

HYDRAIN - INTEGRATED DRAINAGE DESIGN COMPUTER SYSTEM

VOLUME IV. WSPRO - STEP BACKWATER AND BRIDGE HYDRAULICS

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INTRODUCTION

The Water-Surface Profile (WSPRO) computer program has been designed to provide a water-surface profile for six major types of flow situations: (1) unconfined flow, (2) single-opening bridge, (3) bridge opening(s) with guide banks, (4) single-opening, embankment overflow, (5) multiple alternatives for a single job, and 6) multiple openings. This report is intended to introduce WSPRO and guide the user through some of the necessary steps toward the determination of water-surface profiles. Detailed technical and application information can be found in other documents.^(1,2)

WSPRO was originally developed by the United States Geological Survey (USGS) for the Federal Highway Administration (FHWA). The original model was a batch mode mainframe program, written in FORTRAN. Members of the Pooled Fund Project (PFP) decided to use WSPRO as the bridge waterways analysis element of the Integrated Computerized Drainage Design System. WSPRO was downloaded to the microcomputer by the USGS and FHWA. This release of HYDRAIN also incorporates a new graphical interface for developing input files and reviewing program output.

WSPRO requires the creation of an input file, consisting of commands to describe the physical characteristics of a waterway. The program shell or WSPRO Input/Output program facilitates this activity. The commands are placed in a logical sequence, usually from downstream section to upstream to facilitate a step-backwater computation methodology. The input file, established for a specific stream reach pattern by the user, is then executed using the WSPRO program, regardless of how the input file is created.

This documentation consists of three major sections. The first section provides the user with an overview of the components that form the WSPRO program. The second section deals specifically with the technical methodologies used by WSPRO, beginning with a general description of topics, followed by narratives on methodologies and a discussion of relevant formulas and commands. The topics include: a general discussion of water-surface profile computation theory, single opening bridge hydraulics, multiple waterway opening hydraulics, and culvert analysis using the WSPRO program. The third section provides the user with instruction on how to apply WSPRO within the HYDRAIN system.

SYSTEM OVERVIEW

This documentation is aimed at providing information to new users (as well as infrequent or "rusty" users) of WSPRO to bring them to a level of ability sufficient to utilize any feature that WSPRO offers. It is not meant to show every possible type of situation that WSPRO can handle (however examples of several types of situations are demonstrated).

This section will provide an overview of WSPRO by briefly describing its purpose, capabilities and structure. A key to some of the more frequently used terms and concepts is included at the end of this section. The following sections provide more detailed information to help the user make the most of WSPRO. The user is advised to scan the table of contents to see exactly what this text offers, how it is arranged and where to turn for specific information.

CAPABILITIES AND LIMITATIONS

In this section of the applications guide, several of WSPRO's capabilities and limitations will be briefly discussed. The capabilities of WSPRO are:

- Water-surface profile computations in the absence of bridges are generally consistent with the methods used in other models such as the Corps of Engineers HEC-2.
- Any combination of subcritical, critical, and supercritical flow profiles may be analyzed for one dimensional, gradually varied, steady flow.
- Discharge may be varied from cross-section to cross-section to account for tributary and lateral flow gains or losses.
- Up to 20 profiles for different discharges and/or initial water-surface elevations may be computed at one time.
- Initial water-surface elevations for each profile may be specified by the user or computed by the model.
- Variable Manning's roughness coefficients may be specified for any cross-section to reflect roughness changes both horizontally and vertically in the cross-section.
- Up to three different flow lengths for left, central and right portions of a valley may be specified between any two valley cross-sections.

- Users may select the friction-slope averaging technique to be used in the friction loss computations.
- Users may specify the coefficients used to compute energy losses associated with expansion or contraction of flow.
- The model can compute backwater for both free-surface and pressure flow situations at a bridge.
- The model can compute water-surface profiles through bridges for cases where road overflow occurs in conjunction with flow through the bridge opening.
- The effects of guide banks on the water-surface profile are estimated when guide banks data are entered.
- The model can analyze multiple waterway openings for a cross-section, including culverts when used as one of the multiple openings.
- The model can now utilize multiple cross-section templates with second and subsequent templates replacing previous template data. See the notes following the XT command in Appendix C of this volume.

STRUCTURE OF WSPRO

The structure and organization of the WSPRO program is similar to many other computer programs. The program reads data, analyzes it, and outputs information for the user's review. Unlike many other hydraulic analysis programs, WSPRO requires only a single input data file. This data file is made up of a list of user-supplied **commands** that specify (describe) the waterway. All internal analysis by WSPRO is performed according to these commands. Once the commands are assembled into a final working data set, they are collectively called a **command string**. (These concepts are explored in more detail in the following section.) During analysis (program execution), the command string is checked for proper format and executability. Output is generated according to the user-supplied instructions of the command string and sent to a separate output file which the user may in turn send to either a printer or screen display. If a run aborts prematurely (before intended analysis is completed), appropriate descriptive error messages are then sent to the output file. There is also a "status report" feature within WSPRO that displays (on the user's screen) when each command in the command string is being executed, in "echo" format. This allows the user to trace program progress.

KEY TO WSPRO TERMS

The WSPRO Input/Output program greatly eases the task of creating input data sets by automating the process; however, effective use of WSPRO requires an understanding of how to prepare a program data file “manually.” It is, therefore, important to have a clear grasp of the more fundamental modeling terms as they are used in this documentation. The more comfortable the user is with the following terms (and their associated concepts), the easier it will be to put this documentation to use.

- **Command** - A one or two-letter user-supplied "key word" and its associated completed data field, that WSPRO recognizes and accepts as input data for performing a specific task. The user selects these commands according to the function(s) that WSPRO is to perform. Each command must be listed (entered) on a separate line of data. These data lines make up the user's input data set, which is collectively referred to as a **command string** (See entry below.) Command names are one or two-letter "descriptors" (often abbreviations or acronyms) of the tasks that the commands perform. For example, **WS** is the command name for "starting Water-Surface elevation." This command allows for user-provided specifications to initialize water-surface profile computations. A complete listing and explanation of available commands is provided in appendix C.
- **Command string** - An arrangement of **commands** that describes a given system. A command string is the fundamental user-provided data set that allows WSPRO to analyze a site. This data set may be edited to adjust for modifications to the system without having to build a new command string from scratch. Commands and command strings are further discussed in the next section.

TECHNICAL INFORMATION

Bridge waterway design normally requires determination of: (a) the amount of backwater due to the encroachment of the flood plain, and (b) the upstream extent of the bridge-affected water-surface elevations relative to the unconstricted flow elevations. Capabilities of the model must therefore include the ability to compute water-surface profiles through unconstricted valley reaches in addition to profiles through bridges or culverts.

WATER-SURFACE PROFILE COMPUTATION THEORY

WSPRO uses a standard step method similar to that described by Chow to compute backwater in unconstricted valley reaches.⁽³⁾ This method requires description of a series of cross-sections which segment the valley reach into relatively short subreaches. Subreaches should be sufficiently short so that the assumption of gradually varied, steady flow is valid within each subreach.

The standard step method is based upon the principle of conservation of energy, i.e., the total energy head at an upstream section must be equal to the total energy head at a downstream section plus any energy losses that occur between the two sections. Thus, the energy equation between two adjacent cross-sections may be written:

$$h_1 + h_{v_1} = h_0 + h_{v_0} + h_f + h_e \quad (1)$$

Where:

$h_{1,0}$ = Water-surface elevation; 0=downstream, 1=upstream.

$h_{v1,v0}$ = Velocity head.

h_f = Friction loss.

h_e = Expansion/contraction loss.

Each component of the energy equation is dependent upon physical data specific to the site. The velocity head components are derived as a function of conveyance, roughness, flow area, and discharge. Friction losses are also determined as a function of the above parameters, in the form of friction slope calculations, with the addition of a length parameter. Friction slope (or conveyance) may be calculated in any of the following four ways: geometric mean of conveyance, arithmetic average of conveyance, arithmetic average of friction slope, or harmonic mean of friction slope. The contraction and expansion losses are determined as a function of the velocity head differential and a user-specified contraction or expansion coefficient.

A direct solution of the energy equation is not possible when either h_0 or h_1 is unknown, since the associated velocity head and energy loss terms are then also unknown. The model therefore computes the difference in total energy between the sections using an iterative procedure. Successive estimates of the unknown elevation are used to compute the unknown velocity head and loss terms until an absolute value of the energy difference is achieved that is within an acceptable tolerance. Generally the user-specified tolerance (given in the **J1** - Job Parameter command) is on the order of 0.01 m. The default value is 0.006. Should a tolerance exceeding 0.1 be needed to obtain a solution there may be reason to suspect data inadequacies such as an insufficient number of cross-sections.

The model does not provide the capability to obtain a direct solution for a water-surface profile that represents a combination of supercritical and subcritical flow at adjacent cross-sections. However, it is possible that a critical water-surface elevation at one cross-section and either a sub- or supercritical water-surface elevation will satisfy the energy equation. If the appropriate control parameters and cross-sectional information have been specified, and computations have proceeded in the appropriate direction, such a combination represents a correct, acceptable solution for a water-surface profile.

WSPRO is designed, to the greatest extent possible, to reject computed water-surface elevations which are in the incorrect flow regime. Subcritical flow at any point is controlled by downstream flow conditions. Conversely, supercritical flow is controlled by upstream flow conditions. Therefore, subcritical profile computational direction is from downstream to upstream, while supercritical flow computational direction is from upstream to downstream.

The water-surface elevation for critical flow is computed on the basis of minimum specific energy for each cross-section. Trial water-surface elevations are constrained to be greater than minimum ground elevation and less than or equal to the critical water-surface elevation computing downstream. Computing upstream trials are constrained to be greater than the critical elevation. Thus, any trial value satisfying the energy balance equation is automatically in the correct flow regime.

Most of the subcritical profile computations are for flow conditions significantly higher than critical flow making the determination of the elevation of minimum specific energy a much more time-consuming iterative process. Therefore, an attempt is made to avoid computation of critical water-surface elevation for a cross-section unless the flow is near critical flow. A Froude number test is a good alternative method of assuring that a trial elevation that satisfies the energy balance criteria is also in the subcritical flow range. If the computed Froude number is less than a user-specified Froude number test value the trial water-surface elevation will be accepted as a valid subcritical solution.

Since the computed Froude number is only an approximation, at a cross-section where flow is nearly critical, the possibility exists that a valid solution will be rejected. WSPRO therefore determines the critical water-surface elevation to establish the bound of the subcritical flow regime. Any trial elevation at or higher than the critical will be acceptable for upstream computations because the computed critical water-surface elevation is based on minimum specific energy.

At any cross-section where an acceptable solution is not found, in both subcritical and supercritical computations, WSPRO assumes critical flow exists at that cross-section. The model then uses the critical water-surface elevation at that cross-section as the "known" elevation for computing the water-surface profile through the next subreach.

SINGLE-OPENING BRIDGE HYDRAULICS

Computation of the water-surface profile through a stream crossing having a single waterway opening requires definition of a minimum of four cross-sections. In situations where uniformity of channel shape and valley slope permit, it is possible to provide this definition on the basis of a single surveyed cross-section because the model provides fairly flexible data propagation capabilities. These cross-sections are the three unconstricted valley sections, exit, full-valley, and approach, and the bridge opening section as shown in figure 1. A more complicated situation is observed for the single opening case if guide banks are present. An additional cross-section describing the guide banks is required, as shown in figure 2.

The flow situation at a single bridge opening depends upon the relative elevations of the water-surface both upstream and downstream of the bridge with respect to the elevations of the top of the bridge opening (referred to as low steel) and the top of the road grade. Free-water-surface flow occurs when there is insignificant or no contact of water-surface and low steel. Pressure flow through the bridge opening occurs as either submerged orifice flow (the water-surface is in contact with the low steel for the full flow length of the bridge) or orifice flow (only the upstream water-surface is in contact with low steel). Any of these conditions can exist in conjunction with road overflow. Flow classes are designated by number to provide a convenient means of directing computational sequences and identifying output. The flow classes are dependent upon the elevation of the water-surface relative to the elevation of the low steel, which will determine whether free flow or pressure flow exists, and the minimum elevation along the top of the embankment, which determines whether road overflow occurs. Table 1 summarizes the flow classes and the governing elevation relationships.

WSPRO precedes each single-opening bridge analysis with computation of the natural profile from the exit section to the full-valley and approach sections. These data permit determination of the amount of backwater caused by constriction and are also used as the initial trial elevations in the iterative solution for the water-surface profile through the bridge.

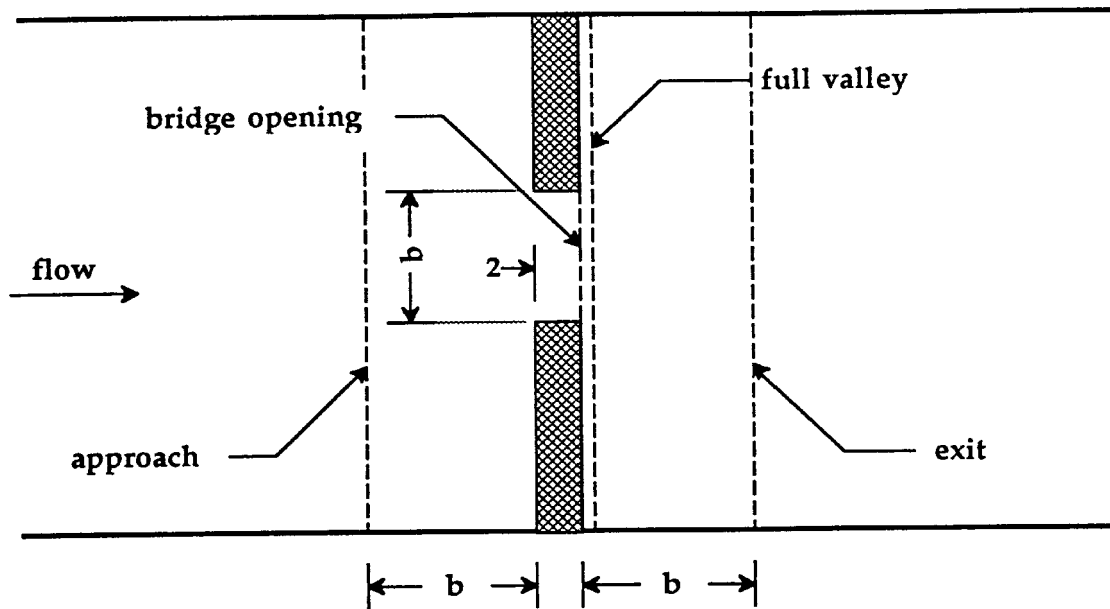


Figure 1. Schematic of single bridge opening.⁽²⁾

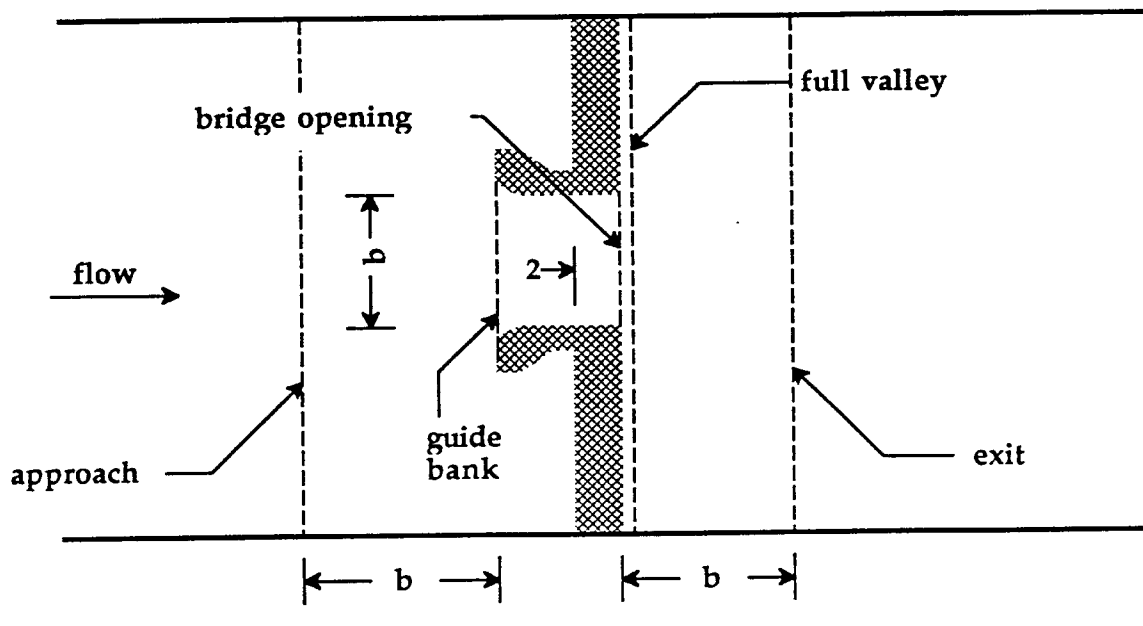


Figure 2. Schematic of single bridge opening with guide banks.⁽²⁾

Table 1. Summary of flow classes for a single bridge opening.

Class #	Relative Elevations							
	Flow Class	Road Overflow	$h_{ds} < y_{ls}$	$h_{ds} > y_{ls}$	$h_{us} < y_{ls}$	$h_{us} > y_{ls}$	$h_{us} < y_{min}$	$h_{us} > y_{min}$
1	free-surface		✓		✓		✓	
2	orifice		✓			✓	✓	
3	submerged			✓		✓	✓	
4	free-surface	✓	✓		✓			✓
5	orifice	✓	✓			✓		✓
6	submerged	✓		✓		✓		✓

h_{ds} =

water-surface elevation immediately downstream of the bridge,

h_{us} =

water-surface elevation immediately upstream of the bridge,

y_{ls} =

low steel elevation, and

y_{min} =

minimum embankment elevation.

Free Surface Flow

Water-surface profile computations for free-surface bridge flow situations are performed in accordance with the methods outlined by Schneider et al.⁽⁴⁾ Improved computed results are attributed primarily to revisions in the computation of friction losses in the vicinity of the bridge.

These revisions include use of an effective flow length from the approach section to the bridge opening section and use of a selected minimum conveyance for the subreaches both upstream and downstream of the bridge opening. Another minor improvement is attributed to the use of an expansion loss between the bridge-opening section and the exit section.

Friction losses depend upon conveyance, discharge, and effective flow length. Since these losses are directly proportional to flow length, it becomes imperative to obtain the best possible estimate of flow length, especially for those cases where the friction loss is a significant component of the energy balance between two sections. Previous computational methods that did compute friction loss components estimated the approach reach friction loss on the basis of the straight-line distance between the approach section and a reference point at the bridge opening. For minor degrees of constriction, this was usually adequate. However, for more significant constrictions, this straight-line distance is representative only of that portion of flow that is generally in direct line with the opening. Flow further away from the opening must flow not only downstream, but also across the valley to reach the opening, thus traveling much farther than the straight-line distance. Therefore, a simplified computational technique was developed and incorporated into WSPRO to compute average streamline length.

Pressure Flow

Free-surface flow cannot exist if there is significant contact of the water-surface with the bridge superstructure. Instead, pressure flow, which is proportional to the square root of the head differential, is established. WSPRO analyzes pressure flow as either orifice or submerged orifice flow depending on the degree of contact between the water-surface and the superstructure. Detailed discussion of the determination of discharge coefficients for each of these cases are found in the Bridge Waterways Analysis Model: Research Report.⁽²⁾

Multiple Waterway Opening Computation Theory

At some stream crossings, especially those across very wide flood plains, waterway openings in addition to the bridge spanning the main flow channel may be either economically and/or hydraulically justified. Various combinations of culverts and/or bridges may be used.

Data requirements for multiple opening situations are similar, but more extensive than those for the single-opening case. One of the basic assumptions in the multiple opening analysis is that the valley can be rationally divided into strips, one strip for each opening, in proportion to the distribution of discharge through the openings and across the valley. Figure 3 represents a typical situation with a centrally located main-channel opening and relief openings on both the left and right flood plains. Unconstricted valley cross-sections are required at the locations indicated by D and U, as well as immediately downstream of the openings at 3F. Section 3F is totally analogous to the full-valley section of the single-opening case. Section D serves as the starting point for analysis of each of the individual openings with a common water-surface elevation and is referred to as the downstream match section. Section U, referred to as the upstream match section, serves as the termination point for the analysis of each individual opening. These match sections must be located such that they satisfy the maximum distance requirements of exit and approach section location for single-opening analysis of each opening. Definition of each opening is also required. Each bridge opening is described as discussed for single-opening situations, that is, with a bridge opening section and, when necessary, a guide bank section.

The portion of the total discharge that will flow through each individual opening is dependent upon both the relative size of each opening and the flow distribution in the appropriate reach. Stagnation points, which are the location of flow division along the interior embankment between adjacent openings, are located in direct proportion to the total flow area of adjacent openings. That is, the distance between the right edge of the left opening and the stagnation point is computed by multiplying the length of embankment between two adjacent openings by the ratio of the left flow opening area to the total flow area of both openings. Boundaries parallel to the flow extended from the stagnation points to both upstream and downstream match sections define the valleystrips for each of the openings. Discharge apportionment uses a channel resistance ratio to define the flow capacities of each valley strip.⁽²⁾

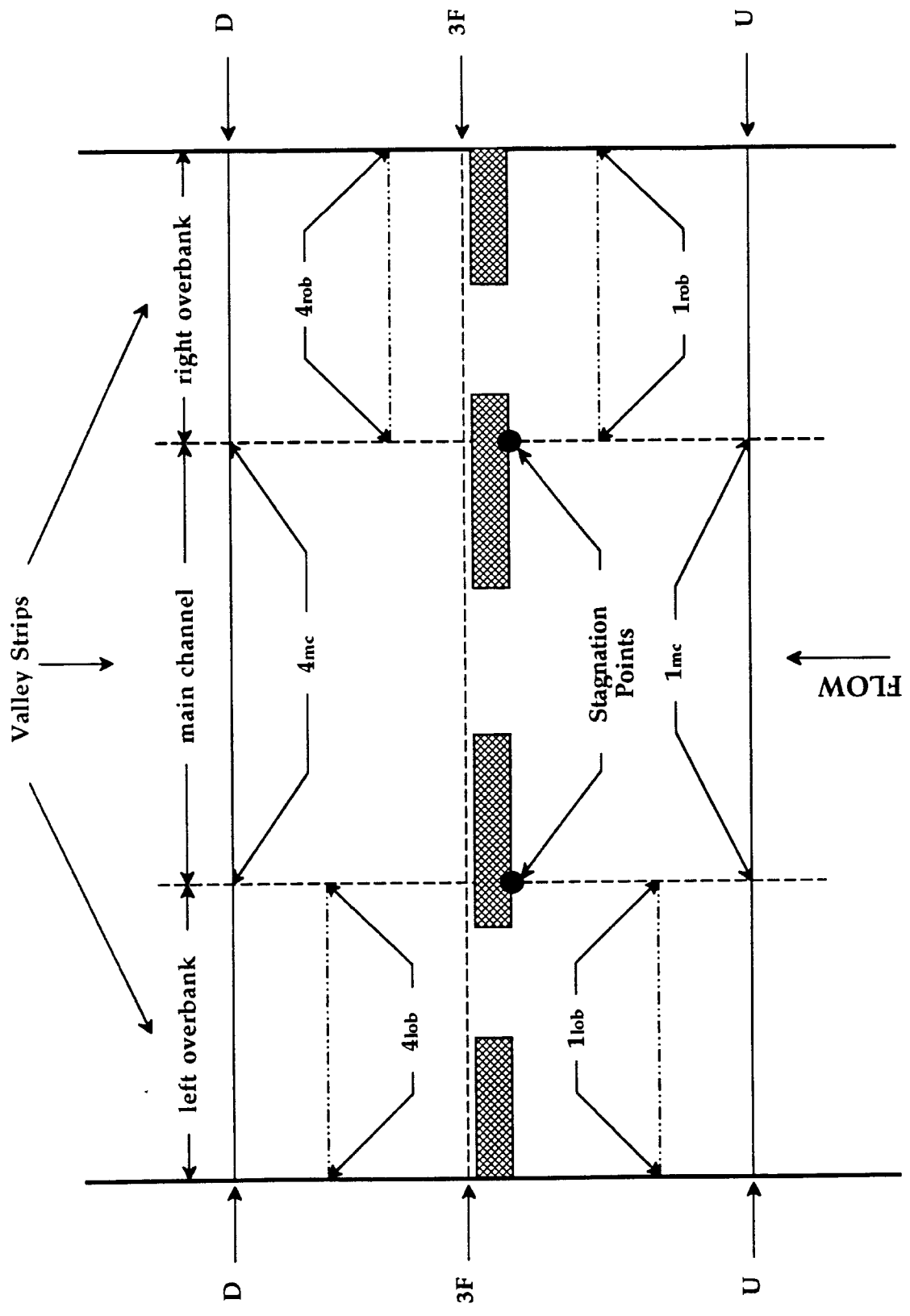


Figure 3. Multiple bridge opening showing valley strips and cross-section locations.⁽²⁾

CULVERT ANALYSIS

At many bridge sites, culverts are used to carry the flow of secondary stream channels and drainage swales through a roadway embankment. These culvert openings are usually designed to pass only low-water flows and, therefore, usually have negligible effect on the overall pattern of flow and backwater at the flood flows considered in most bridge waterway analyses. In some cases, however, small bridges in submerged flow under wide roadways may become more hydraulically like culverts than like bridges. In other cases, large culverts may carry significant fractions of the total flow and may have significant effects on the backwater pattern.

In WSPRO, culverts are considered only in the context of multiple opening bridge situations. The general plan of the culvert computations is to compute the headwater elevation corresponding to a given discharge and given tailwater elevation for a culvert of given dimensions and material. The culvert dimensions and material are specified by the user in the **CG** and **CV** commands.

The tailwater elevation is the result of step-backwater computations in the reach downstream of the culvert. The portion of the total discharge that is to be conveyed by the culvert is computed by a flow-apportionment procedure. The water-surface elevation at the upstream match section for the culvert valley strip corresponding to the computed headwater elevation is determined by step-backwater computations.

The wide range of flow patterns exhibited by culverts under varying discharges and tailwater elevations is divided into two broad flow types, inlet and outlet control. For each type of control, the headwater elevation is computed independently, using different hydraulic principles and coefficients. The higher of these headwater elevations is adopted as appropriate for conservative analysis.

Under inlet control, the flow through the culvert is controlled by conditions at the inlet: the shape and cross-sectional area of the culvert barrel, the beveling or rounding of the inlet edge, the degree of projection of the barrel from the embankment, and the headwater depth. Barrel slope also has a minor effect on culvert capacity. Barrel roughness, length, and tailwater depth have no effect on inlet controlled flow. Inlet control typically governs when the culvert barrel is short, steep, and smooth, and when there are good getaway conditions at the outlet.

The headwater depth is the distance between the energy gradeline and the inlet invert. Thus it includes the contribution of the velocity head at the headwater section. However, in culvert design the velocity head is usually such a small component of the total head that separating it from the total head is not justified. Headwater is usually assumed to be ponded with zero velocity head, and the headwater depth computed from the inlet control equation is taken as the height of the water-surface above the inlet invert. The critical depth in the culvert barrel is characterized by the condition that the velocity head equals half the mean depth.

Under outlet control, the flow through the culvert is controlled by conditions in the culvert barrel and at the outlet, as well as by conditions at the inlet. Thus, barrel roughness, length, slope, headwater and tailwater elevations become the primary determinants of flow through the culvert.

Outlet control typically governs long, flat, rough-barreled culverts with high tailwater and obstructed getaway conditions at the outlet.

Under the usual conditions of culvert design, the outlet-controlled culvert barrel flows full or nearly full for most or all of its length. The full flow condition is checked by computing the hydraulic grade line and noting whether it intersects the top of the culvert barrel. If it is not full flow, backwater calculations have to be used to define the water-surface profile through the culvert barrel. Supercritical flow need not be considered because the inlet will control when supercritical flow occurs in the barrel.

USER DOCUMENTATION

Effective use of WSPRO requires an understanding of the interaction between user and software. While the previous chapter described what WSPRO does, this chapter explains how to interact with the software to achieve desired results. More information pertaining to WSPRO can be found in the WSPRO Users Manual.⁽¹⁾

THE COMMAND APPROACH - ORGANIZING THE DATA

WSPRO operates through the command language concept. This means that data entry and data analysis are all dictated by user-supplied commands. A command is a very specific entity that describes one basic task that WSPRO can recognize. There is only a set number of commands in WSPRO's vocabulary and each must follow a specific format. A list, to date, of these commands along with their definitions and format specifications is included in appendix C.

A glossary of all the commands is shown in table 2. Detailed descriptions and special notes for each command are provided by the software as long helps (obtained by using the <F1> key) and are also reproduced in appendix C. Commands operate in "free format" fashion; that is, a space [] or a comma [,] are parameter subfield separators that may be used in any amount between each parameter value (spacing between subfields is not critical). Because the HYDRAIN editor is best suited for editing free format data files, WSPRO has a utility that allows the user to input data in free format (the *F command).

Commands are the data that a user must specify to describe a system for analysis. These commands may be arranged in almost any order, provided they follow a few, simple guidelines. These guidelines ensure that the user's site is described appropriately and logically, and will become more clear as the user gains familiarity with this section and the examples provided in the appendix. Once these commands are arranged in their final working order, they are collectively referred to as a command string. The command string is what WSPRO needs to define a system model for analysis.

The output provides detailed information on the resulting calculations using keywords. Table 3 presents the output keywords and their definitions.

Table 2. Input record types.

TITLE INFORMATION

T1, T2, T3 - Alphanumeric data for identification of output.

JOB PARAMETERS

J1 - Error tolerances, test values, etc.
UT - User defined special tabling parameters.

PROFILE CONTROL DATA

Q - Discharge(s) for profile computation(s).
WS - Starting water-surface elevation(s).
SK - Energy gradient(s) for slope-conveyance computation of starting water-surface elevation(s).
EX - Execution instruction, computation direction(s), and floodways.
ER - Indicates end of input (End of Run).

CROSS-SECTION DEFINITION - Header Records (required for each cross-section)

XS - Unconstricted valley section.
BR - Bridge-opening section.
GB - Guidebank section (SD record still recognized).
XR - Road-grade section.
XS - Approach section (AS record no longer required).
CV - Culvert section.
XT - Template section.

CROSS-SECTION DEFINITION - Cross-Sectional Geometry Data

GR - x,y-coordinates of ground points in a cross-section with exceptions at bridges, guidebanks, and culverts; and for data propagation.

CROSS-SECTION DEFINITION - Roughness Data

N - Roughness coefficients ('n'-values).
SA - x-coordinates of subarea breakpoints in cross-section.
ND - Hydraulic-depth breakpoints for vertical variation of roughness.

CROSS-SECTION DEFINITION - Flow Length Data

FL - Flow lengths and (or) friction slope averaging technique.

Table 2. Input record types (continued).

CROSS-SECTION DEFINITION - Special Data

Bridge Section Data (COMPONENT MODE - no GR data)

- BL - Bridge length and location.
- BC - Bridge low-chord parameters.
- AB - Abutment slopes.
- CD - Opening type and configuration.
- PD - Pier or pile data (PW record is still recognized).
- KQ - Conveyance breakpoints (KD record is still recognized).

Bridge Section Data (COORDINATE MODE - requires GR data)

- CD - Opening type and configuration.
- AB - Abutment toe elevations.
- PD - Pier or pile data (PW record is still recognized).
- KQ - Conveyance breakpoints (KD record is still recognized).

Approach Section Data

- BP - Horizontal datum correction between bridge and approach sections.

Road-grade Section Data

- BP - Horizontal datum correction between bridge and road-grade sections.

Culvert Section Data

- CG - Culvert geometry.
- CC - Culvert coefficients.

Scour Computation Record

- DA - Abutment scour data.
- DC - Contraction scour data.
- DP - Local pier scour data.

Effective Flow Record

- EF - Effective flow input.

Floodway Computation Record

- FW - Mandatory record for floodway analysis to specify parameters.
- FS - Optional record for floodway analysis to specify global surcharges.

Metric/English Record

- SI - Metric/english input/output

Template Geometry Propagation

- GT - Replaces GR data when propagating template section geometry.

Table 3. Output key words.

WSEL	-	Water-surface elevation	BLN	-	Bridge opening length
VHD	-	Velocity head	XLAB	-	Abutment station, left toe
Q	-	Discharge	XRAB	-	Abutment station, right toe
SRD	-	Section reference distance	LSEL	-	Low steel elevation
EGL	-	Energy grade line	FLOW	-	Flow classification code
ERR	-	Error in energy/discharge balance	TYPE	-	Bridge opening type
FLEN	-	Flow distance	C	-	Coefficient of discharge
SLN	-	Straight-line (SRD) distance	PPCD	-	Pier or pile code
HF	-	Friction loss	P/A	-	Pier area ratio
HO	-	Other losses	Q	-	Flow over road
VEL	-	Velocity	WLEN	-	Weir length
FR#	-	Froude number	LEW	-	Left edge of weir
CRWS	-	Critical water-surface elevation	REW	-	Right edge of weir
K	-	Cross-section conveyance	DMAX	-	Maximum depth of flow
AREA	-	Cross-section area	CAVG	-	Average weir coefficient
ALPHA	-	Velocity head correction factor	HAVG	-	Average total head
BETA	-	Momentum correction factor	DAVG	-	Average depth of flow
XMAX	-	Maximum station in cross-section	VMAX	-	Maximum velocity
YMAX	-	Maximum elevation in cross-section	VAVG	-	Average velocity
XMIN	-	Minimum station in cross-section	M(K)	-	Flow contraction ratio
YMIN	-	Minimum elevation in cross-section	KQ	-	Conveyance of Kq-section
SPLT	-	Stagnation point, left	XLKQ	-	Left edge of Kq-section
SPRT	-	Stagnation point, right	XRKQ	-	Right edge of Kq-section
SKEW	-	Skew of cross-section	M(G)	-	Geometric contraction ratio
XSWP	-	Cross-section wetted perimeter	OTEL	-	Road overtopping elevation
XSTW	-	Cross-section top width			
LEW	-	Left edge of water			
REW	-	Right edge of water			
EX	-	Expansion loss coefficient			
CK	-	Contraction loss coefficient			

THE HYDRAIN ENVIRONMENT

For those users who have obtained WSPRO as part of the Federal Highway Administration's HYDRAIN package, consult the HYDRAIN Volume I documentation for information on how to use the software system.

There are three methods by which WSPRO can be run within the HYDRAIN environment. One method is to run WSPRO from the HYDRAIN editor. This allows the user the option of immediate review and editing capabilities. The second method is to run WSPRO from the HYDRAIN shell using the **Execute** option. Finally, WSPRO can be executed from the DOS prompt. Discussion of all three options is in the HYDRAIN documentation.

Upon completion of the run, the output file is automatically assigned an **.LST** filename extension. The output file contains an echo of the input data and the results. The output file may contain messages describing warnings or errors encountered during execution. These messages are useful in debugging a data set.

THE WSPRO INPUT/OUTPUT PROGRAM

The WSPRO Input/Output Program is a Graphical User Interface (GUI) program and set of supporting files which allow a user to interface with the WSPRO model in a Windows-like environment. This facilitates viewing and editing input data, output data, cross-sections and other aspects of interaction with WSPRO. The Input/Output Program is not intended to replace familiarity with the WSPRO mode. Its objective is to facilitate interaction with the model. Use of the WSPRO Input/Output Program requires a VGA monitor or better.

Much of the user's interaction with the program is done with the mouse. Actions which can be taken with the mouse are pointing, clicking, left-clicking, right-clicking, double-clicking, dragging and "dragging and dropping." The user gets visual feedback of actions taken by movements of the arrow-shaped cursor on the screen.


- Pointing is done by moving the mouse so the cursor points at a desired location on the screen. As the mouse is moved, the cursor tracks its movements.
- Left- and right-clicking are done by pointing to a desired location on the screen and then operating the mouse's left or right button, respectively, by pressing and then releasing the appropriate mouse button. Right-clicking on an icon button displays a short help message about that object at the bottom of the screen.
- Double-clicking is done by pointing at the desired screen object and then pressing and releasing the left mouse button quickly in succession. Pointing and left-clicking is the standard action to take to select an object for use. Double-clicking both selects the object for use and causes a logical action to be taken on it.
- Dragging is done by pointing to a desired location on the screen, pressing (and holding) the left mouse button, moving the mouse to another desired location on the screen, and then releasing the mouse button.
- Dragging and dropping is a special capability offered by some screen objects. Physically, it is done exactly like dragging; however, there are additional visual and functional effects. When the mouse button is pressed on an object offering drag-and-drop functionality, the cursor will change to indicate it has been "loaded" and is prepared for the drop. When the mouse is moved to the target area of the screen and the mouse button released, the cursor returns to its normal appearance and the action represented by the dragged icon takes effect.




The Screen


The WSPRO Input/Output Program divides the screen into four areas: the Command Bar, the Tool Bar, the Schematic Layout Window, and the Browser Window. These areas are used in conjunction with each other to carry out WSPRO-related tasks. Only one of these areas is "active" at a time. The active area is indicated by an orange box which highlights the


perimeter of the active area. In addition to the orange box to indicate the active window, the title bars of the Schematic Layout and Browser windows are green when active and white when not.

Some screen control features are common to more than one area. These are discussed below.

 *Up, down, left and right*, respectively. These icon buttons are the up, down, left, and right button icons, respectively. There are left and right buttons at the left end of the Command Bar and one of each on appropriate ends of the scroll bars in the Schematic Layout and Browser windows. Clicking on one of these buttons causes the affected bar or window to scroll in the indicated direction revealing additional information or icon buttons.

 *Maximize* and *minimize window*, respectively. One of these buttons can always be found in the upper right-hand corner of the Schematic Layout and Browser windows. When the  button is present and left clicked, the affected window will expand to full-screen size. When the  is present and left-clicked, the window contracts to its normal size and place on the screen.

 *Clear*. This button is found in the upper left-hand corner of the Schematic Layout and Browser Windows and in dialog boxes. In the Schematic Layout and Browser windows, left-clicking it causes whatever information is displayed there to be cleared. In dialog boxes, it has the same effect as the Cancel button.

 *Scroll Bar*. A vertical or horizontal scroll bar appear at the bottom or right edge, respectively, of the Schematic Layout and Browser windows. (Only a horizontal scroll bar is shown here.) Clicking on the arrow button at either end of the scroll bar causes the affected display to scroll in increments of one line or character. Dragging the "thumb" (the button icon on the scroll bar between the arrow buttons) causes the display to scroll an amount proportional to the distance the thumb is dragged. Clicking in the gray area between the thumb and the arrow causes the display to scroll an amount equal the one window's width.

The Command Bar

The command bar contains 21 button icons which, when clicked with the mouse, carry out specific actions. Not all 21 buttons are visible simultaneously. At the left end of the command bar are left and right scroll buttons. Clicking these buttons causes the command bar to "scroll" making the "hidden" buttons "scroll" into view for access. The actions associated with each button is described below.



Open/Create. Summons a dialog from which the user selects and loads a particular existing input data set or creates a new one.



Save. Saves the currently open data set to disk.



Run. Executes (analyzes) the currently open data set and presents the output in the Browser window.



Quit. Quits and exits the WSPRO Input/Output Program.



Flow Characteristics. Summons a scrollable dialog box where the user enters flow characteristics and inserts an appropriate Q command in the data set.



Title. Summons a dialog for entry of up to three lines of textual information inserted into the ASCII data set as T1, T2, and T3 commands.



DA Command. Summons a scrollable dialog box which allows entry of abutment scour information and inserts a DA command into the ASCII data set.



DC Command. Summons a scrollable dialog box for entry of live-bed and clear-water scour information and inserts an appropriate DC command into the ASCII data set.



DP Command. Summons a scrollable dialog box for entry of parameters with which to perform local pier scour computations and inserts a DP command into the ASCII data set.



HP command. Summons a scrollable dialog box where the user provides hydraulic property information and inserts an HP command in the data set.



J1 Command. Summons a dialog for entry of computational control parameters and inserts a J1 command into the data set.



UT command. Summons a scrollable dialog box for entry of parameters specifying user-defined output tables by inserting a UT command in the data set.



Input. Summons the currently established input data set to the Browser window. Whatever was previously displayed in the Browser window is cleared before the input file is displayed. (No input data are lost when the Browser window is cleared.)



Output. Summons the current output data file to the Browser window. Whatever was previously displayed in the Browser window is cleared before the output file is shown. (No output data are lost when the Browser window is cleared.)



Section. Summons a scrollable dialog in which the names of available output cross-sections are displayed. Left-clicking on a cross-section name and the OK button (or double-clicking on the cross-section name) displays the cross-section with water-surface elevation in the Browser window. (Note: Since no output cross-sections are available until after the input data set has been analyzed, the dialog will be empty until the input data are analyzed.)



Profile. Summons a scrollable dialog in which the names of available output profiles are displayed. Left-clicking on a profile name and the OK button (or double-clicking on the profile name) displays the cross-section and water-surface elevation in the Browser window. (Note: Since no output profile are available until after the input data set has been analyzed, the dialog will be empty until the input data are analyzed.)



Paths. Allows the user to change the default path and file name information. (Not implemented in the current program.)



Units. Summons a dialog where the user sets the unit system for the input data set and inserts and appropriate SI command in the data set.



Device. Allows the user to set the default output device. (Not implemented in the current program.)



Globals. Summons a dialog in which the user specifies global defaults. (Not implemented in the current program.)



Graphic Defaults. Summons a dialog in which the user specified graphic defaults. (Not implemented in the current program.)

The Tool Bar

The Tool Bar becomes active when clicked. This is indicated by the orange box surrounding its three icon buttons. The tools in the Tool Bar are used to select and view elements of the WSPRO data set and its output. Icon buttons are used by dragging and dropping them onto the icons attached to the River in the Schematic Layout window. The reverse,

dragging and dropping the attached icons from the Schematic Layout window onto these buttons, has the same effect. The three buttons are:



Edit. Summons the dialog associated with that header. This allows the user to edit an existing header. (Using this icon button has the same effect as double-clicking an attached icon.) Whatever was previously displayed in the Browser window is first cleared. (No data are lost by clearing the Browser window.)



Graph. Summons a graph of that element to the Browser window. Whatever was previously displayed in the Browser window is first cleared. (No data are lost by clearing the Browser window.)



Print. Sends the current data to the output device.

The Schematic Layout Window

The Schematic Layout window normally occupies the left side of the screen. It becomes "active" when left-clicked. This is indicated when its title bar turns green and the orange box surrounds it. When no header information is available in the data set, most of the window is blank containing only a representation of a channel labeled "RIVER".

To the far left of the Schematic Layout is an area labeled "Header" containing eight icon buttons. The top six of these buttons represent header records. To use one of these icons, drag and drop it on the "RIVER" in the Schematic Layout window. This will summon a dialog box in which the user can specify parameters associated with that header and attach an icon to the River to indicate the header is present in the data set. Initially, the icon will attach to the River at the top, but its location along the River will change when its location is edited in the corresponding dialog box.

Once attached to the River, information associated with these icons can be viewed and modified. Dragging and dropping an attached icon on the Edit, Graph, or Print icons causes an edit, graph, or print action, respectively, to be carried out on the information associated with the dragged icon. (The reverse action, dragging and dropping the Edit, Graph, or Print icons on an attached header icon, has the identical effect.) Left-clicking on an attached icon selects it as indicated by highlighting around its perimeter. Double-clicking on an attached icon summons its dialog box so data associated with that element can be edited.

The six header icons are:



XS Header. When dragged to the River in the Schematic Layout window, this icon summons a dialog box where the user sets cross-section information.



BR Header. When dragged to the River in the Schematic Layout window, this icon summons a dialog box where the user sets bridge cross-section information.



CV Header. When dragged to the River in the Schematic Layout window, this icon summons a dialog box where the user sets culvert cross-section information.



GB Header. When dragged to the River in the Schematic Layout window, this icon summons a dialog box where the user sets guidebank cross-section information.



XR Header. When dragged to the River in the Schematic Layout window, this icon summons a dialog box where the user sets road-grade cross-section information.



XT Header. When dragged to the River in the Schematic Layout window, this icon summons a dialog box where the user sets template cross-section information. See notes following the XT command in Appendix C of this volume.

Two of the icons under the Header title allow the user to edit header records. These icons are also "drag and drop" icons.



Clipboard. Dragging and dropping an icon attached to the River onto the Clipboard icon (or vice versa) creates a copy of the dragged header information and summons its dialog box for the user to edit. The two icon button images shown represent an empty and a loaded clipboard, respectively.



Trash can. Dragging an attached header from the River to the trash can icon (or vice versa) deletes the header from the data set.

The Browser Window

The Browser window allows the user to view both textual and graphical input and output information. It is a "read only" viewer and does not allow files shown to be edited as text. When occupying only half the screen, the Browser window can be enlarged to full screen by left-clicking on the button at its upper-right corner. Left-clicking the button in the same corner again causes the Browser window to reduce to its normal size. When the information being Browsed contains more data than can be displayed in the window, the scroll bars can be used to access the additional data. Graphical data are always displayed in a format which fits within the boundaries of the Browser window, regardless of its size.

Dialog Boxes

Not all interaction is done through the mouse and screen. Text input to the Program is made by the user with the keyboard and accepted by the Input/Output Program in dialog boxes. Dialog boxes may contain buttons, text fields, and scroll bars. When a dialog box is presented, the user can left-click in a text field to begin data entry in that field. Clicking on a radio button (circular) sets the associated property. Sometimes, further data is associated with the property set by a particular radio button, so the Program presents a further dialog box to accept the additional data. When too many fields are needed to display all the available fields within the space of the dialog box, a vertical scroll bar is available on the right side of the dialog box allowing the user to scroll up and down to reach all the available data fields. Once all the data is entered and the choices made, the user dismisses the dialog box by left-clicking on the OK button. If the user left-clicks on the Cancel button, conditions are reset to the state which existed before the dialog was summoned.

APPENDIX A: BENCHMARK EXAMPLES

The following examples serve to illustrate the types of analyses that WSPRO can perform. While these examples are not intended to illustrate all of the options within WSPRO, they are intended to satisfy the following four objectives:

1. Provide guidance for creating command strings.
2. Demonstrate uses for many of the commands.
3. Provide information on how to set up a problem.
4. Demonstrate what to expect for output.

In particular, the examples are used to illustrate two flow situations: unconstricted flow and a single-opening bridge. Example two "builds" on example one so that the user may get a "feel" for the necessary data required to create a more complicated waterway. The two examples presented in this appendix illustrate the following options:

1. Water-surface profile computation without considering bridges.
2. Simple single-opening bridges.

Example One: Unconstricted Water-surface Profile Computations

Problem:

Given the following site conditions, for a proposed bridge site, determine the water-surface profile for the unconstricted valley. The stream reach is about 1 km long; is relatively straight; cross-section geometry remains the same throughout; bed slope varies along the reach. Due to the uniformity of the reach, only one cross-section will be required. The section is located at the center of the proposed bridge site at a section reference distance (SRD) of 750 m. A gauging station is located at SRD 300 m, providing a stage-discharge relation at that location. Figures 4 and 5 illustrate the cross-sectional and channel profiles.

Input data are organized into five general groups: (1) title information; (2) job parameters; (3) profile control data; (4) cross-section definition (that includes cross-section coordinate, roughness data and cross-section information subgroups); and (5) display and execution commands. Each group may be further broken down into subgroups. The record types are defined by a one or two character identifier. Example one will be input in the following manner. The input data set will follow the group descriptions.

Identifiers **T1**, **T2**, **T3** (Title information) provide the user with an area in which output identification information is entered. This information can be site location data, comments, report names, etc.

Two job parameter data records (with identifiers **J1**, **UT**) are available to define parameters pertaining to the profile computations in their entirety. A **J1** record is used to specify the computational control parameters.

If the default values are acceptable, then ignore **J1**. Likewise, the **UT** record is not used if using default values. The **UT** record can specify parameters for special output tables. Default values for **UT** indicate that no special output tables are desired. In this case, default values are used.

For each water-surface profile to be computed the following information is required: (a) discharge - **Q**; (b) starting elevation - **WS**, or energy slope - **SK**; and (c) computation direction - **EX**. After identifying the type of data, the values may be input in a free format. Attention to spacing may make it easier for the user to re-interpret the data later on.

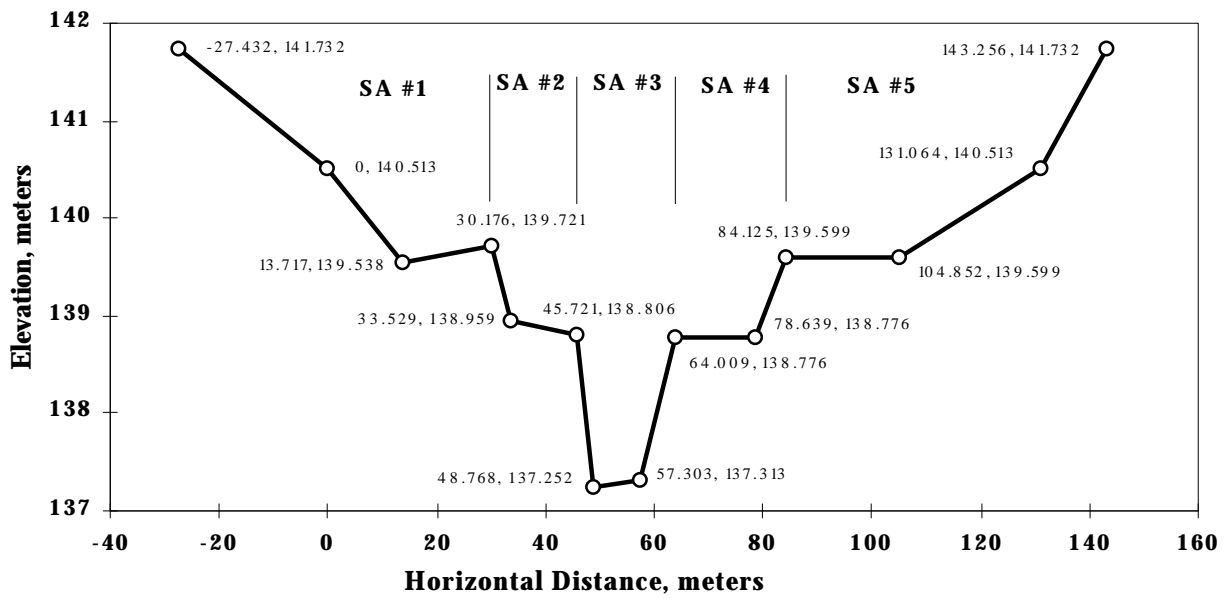


Figure 4. Example cross-section.⁽¹⁾

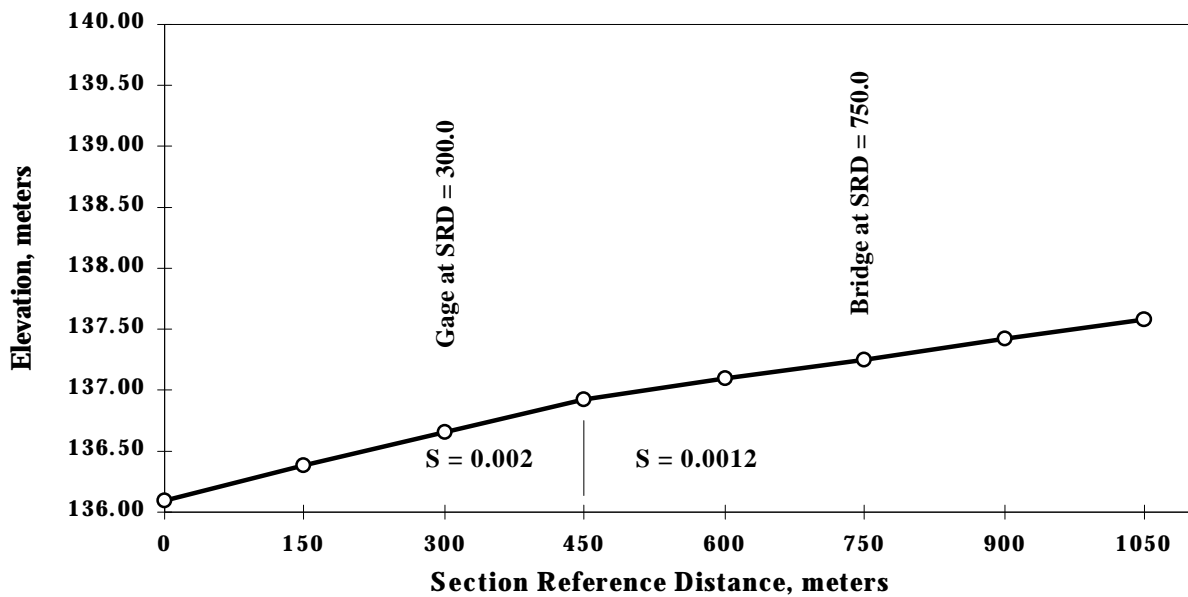


Figure 5. Example channel profile.⁽¹⁾

In this example, three different profiles will be considered. Each profile will contain a value of discharge with its respective starting water-surface elevation. For each entry on the **Q** record there must be a corresponding entry on a **WS** or **SK** and an **EX** identifier. The profile control data are shown below:

Q (m ³ /s)	WS (m)
-----	-----
84.90	139.056
127.35	139.385
169.92	139.629

The cross-section definition will be separated into three subgroups: cross-section coordinates, roughness coefficients, and cross-section information.

1. Cross-Section Coordinates

Assuming a uniform nature of the reach lends itself readily to the use of template sections, horizontal geometry may be: (a) used without any adjustment, (b) expanded or contracted by a scale factor, (c) partially used by using selected portions of the section. Vertical geometry may also be: (a) used without adjustment, (b) shifted by a constant, (c) shifted by a product of valley slope and SRD difference. These parameters are entered using a **XT** record and the corresponding SRD; then, **GR** records define the horizontal and vertical cross-section data. WSPRO provides the ability to specify expansion and contraction energy loss coefficients. In this case, 0.5 and 0.1 are used, respectively, in the **XS** record at SRD 300.

2. Roughness Data

Figure 4 shows that a cross-section may be made up of several subareas characterized by different geometry or roughness. Values of Manning's n may be specified in **N** records for each of these subareas. An n value is entered for the bottom of the subarea as well as the top. The hydraulic depths associated with these values of n are coded in **ND** records specifying first the bottom depth at and below which the bottom n is applicable. Between these depths a linear interpolation determines n. The **SA** records provide the right most X ordinate of each subarea. Manning's n values are summarized as follows:

Subarea	Low Depth Range (m)	n	High Depth Range (m)	n
1	≤ 0.305	0.07	≥ 0.914	0.06
2	≤ 0.61	0.06	≥ 1.524	0.05
3	≤ 0	0.045	≥ 0.305	0.035
4	≤ 0.3305	0.06	≥ 1.219	0.05
5	≤ 0.305	0.07	≥ 0.914	0.06

3. Cross-Section Information

The user may consider unique cross-sections by using the **XS** record and providing data pertinent to that particular cross-section. In this example, this means entering information for a cross-section at SRD 450.0 and every 150 m to upstream of the bridge site at SRD 1050.0.

Finally, the **EX** (Execution) record, corresponding to the **Q** and **WS** records, instructs the model to begin execution of the profile computations. The default direction of computation is upstream (for subcritical and/or critical flow), which is the case in this example. The **ER** or **END** record indicates the end of the run.

Input File: WSPRO1.WSP

```
*F
SI 1
T1      Example One: Simple Unconstricted Flow - Metric
T2      FHWA Model for Water Surface Profile Computations
*
Q        84.90      127.35      169.92
WS        139.056    139.385    139.629
*
XT  SURVY 300.0
GR        -27.432, 140.982      0.000, 139.763      13.717, 138.788
          30.176, 138.971      33.529, 138.209      45.721, 138.056
          48.768, 136.502      57.303, 136.563      64.009, 138.026
          78.639, 138.026      84.125, 138.849      104.852, 138.849
          131.064, 139.763      143.256, 140.982
*
XS  GAGE  300.0 * 0.5 0.1
N        0.070, 0.060      0.060, 0.050      0.045, 0.035
N        0.060, 0.050      0.070, 0.060
ND       0.305, 0.914      0.610, 1.524      0.000, 0.305
ND       0.305, 1.219      0.305, 0.9144
SA        30.176      45.721      64.009      84.125
*
XS  XS2   450.0 * * * 0.002
XS  XS3   600.0 * * * 0.0015
XS  XS4   750.0
XS  XS5   900.0
XS  XS6  1050.0
*
EX
ER
```

Discussion of output:

Initially, data in the input data file are echoed, processed and saved. The data for the cross-section "SURVY" are used to compute the X, Y coordinate pairs for the remaining cross-sections. The parameter in the **GT** record identifies the shift from $SRD = 750$ to $SRD = 300$. The "max - min" points are calculated and all data are summarized.

Upon completion of the input echo and data summary, the model calculates a water-surface profile for each of the coded discharges.

Output File: WSPRO1.LST

```
***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Run Date & Time: 10/15/97 06:10 am   Version V070197
Input File: WSPRO1.WSP   Output File: WSPRO1.LST
*-----*
*F
***                               Input Data In Free Format                               ***

SI  1

Metric (SI) Units Used in WSPRO

Quantity      SI Unit      Precision
-----
Length        meters      0.001
Depth         meters      0.001
Elevation     meters      0.001
Widths        meters      0.001

Velocity      meters/second  0.001
Discharge     cubic meters/second  0.001
Slope         meter/meter   0.001

Angles        degrees      0.01
-----

T1      EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
T2      FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS
Q        84.90      127.35      169.92

*** Processing Flow Data; Placing Information into Sequence 1 ***

WS      139.056      139.385      139.629
```

```

***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*
EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

*-----*
* Starting To Process Header Record SURVY *
*-----*

XT SURVY 300.0
GR -27.432, 140.982 0.000, 139.763 13.717, 138.788
GR 30.176, 138.971 33.529, 138.209 45.721, 138.056
GR 48.768, 136.502 57.303, 136.563 64.009, 138.026
GR 78.639, 138.026 84.125, 138.849 104.852, 138.849
GR 131.064, 139.763 143.256, 140.982

*** Completed Reading Data Associated With Header Record SURVY ***
*** Storing Template Header Record Data In Memory ***

*** Data Summary For Header Record SURVY ***
SRD Location: 300. Valley Slope: ***** Error Code 0

X,Y-coordinates (14 pairs)
X Y X Y X Y
-----
-27.432 140.982 .000 139.763 13.717 138.788
30.176 138.971 33.529 138.209 45.721 138.056
48.768 136.502 57.303 136.563 64.009 138.026
78.639 138.026 84.125 138.849 104.852 138.849
131.064 139.763 143.256 140.982

Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 140.982 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 140.982 )
Minimum Y-Elevation: 136.502 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 140.982 ( associated X-Station: -27.432 )

*-----*
* Finished Processing Header Record SURVY *
*-----*

```

```

***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*
EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

*-----*
* Starting To Process Header Record GAGE *
*-----*

XS  GAGE  300.0 * 0.5 0.1
N      0.070, 0.060      0.060, 0.050      0.045, 0.035
N      0.060, 0.050      0.070, 0.060
ND     0.305, 0.914      0.610, 1.524      0.000, 0.305
ND     0.305, 1.219      0.305, 0.9144
SA      30.176      45.721      64.009      84.125

*** Completed Reading Data Associated With Header Record GAGE ***
*** Storing X-Section Data In Temporary File As Record Number 1 ***

*** Data Summary For Header Record GAGE ***
SRD Location:      300. Cross-Section Skew:      .0 Error Code 0
Valley Slope:      .00000 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion:      .50 Contraction:      .10

X,Y-coordinates (14 pairs)
X      Y      X      Y      X      Y
-----
-27.432  140.982      .000  139.763      13.717  138.788
30.176   138.971     33.529  138.209     45.721  138.056
48.768   136.502     57.303  136.563     64.009  138.026
78.639   138.026     84.125  138.849    104.852  138.849
131.064   139.763    143.256  140.982
-----

Minimum and Maximum X,Y-coordinates
Minimum X-Station:      -27.432 ( associated Y-Elevation:  140.982 )
Maximum X-Station:      143.256 ( associated Y-Elevation:  140.982 )
Minimum Y-Elevation:     136.502 ( associated X-Station:     48.768 )
Maximum Y-Elevation:     140.982 ( associated X-Station:     -27.432 )

Roughness Data ( 5 SubAreas )
SubArea  Transition  Roughness  Hydraulic  Horizontal
          Point      Coefficient  Depth      Breakpoint
-----
1         Bottom      .070         .305        ---
          Top        .060         .914        ---
          --         ---         ---         30.176
2         Bottom      .060         .610        ---
          Top        .050         1.524       ---
          --         ---         ---         45.721
3         Bottom      .045         .000        ---
          Top        .035         .305        ---
          --         ---         ---         64.009
4         Bottom      .060         .305        ---
          Top        .050         1.219       ---
          --         ---         ---         84.125
5         Bottom      .070         .305        ---

```

Top .060 .914 ---

* Finished Processing Header Record GAGE *

```

***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*
EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

*-----*
* Starting To Process Header Record XS2 *
*-----*

XS XS2 450.0 * * * 0.002

*** Completed Reading Data Associated With Header Record XS2 ***
*** No Roughness Data Input, Propagating From Previous Section ***
*** Storing X-Section Data In Temporary File As Record Number 2 ***

*** Data Summary For Header Record XS2 ***
SRD Location: 450. Cross-Section Skew: .0 Error Code 0
Valley Slope: .00200 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (14 pairs)
X Y X Y X Y
-----
-27.432 141.282 .000 140.063 13.717 139.088
30.176 139.271 33.529 138.509 45.721 138.356
48.768 136.802 57.303 136.863 64.009 138.326
78.639 138.326 84.125 139.149 104.852 139.149
131.064 140.063 143.256 141.282
-----

Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 141.282 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 141.282 )
Minimum Y-Elevation: 136.802 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 141.282 ( associated X-Station: -27.432 )

Roughness Data ( 5 SubAreas )
SubArea Transition Roughness Hydraulic Horizontal
Point Coefficient Depth Breakpoint
-----
1 Bottom .070 .305 ---
Top .060 .914 ---
-- 30.176
2 Bottom .060 .610 ---
Top .050 1.524 ---
-- 45.721
3 Bottom .045 .000 ---
Top .035 .305 ---
-- 64.009
4 Bottom .060 .305 ---
Top .050 1.219 ---
-- 84.125
5 Bottom .070 .305 ---
Top .060 .914 ---

*-----*
* Finished Processing Header Record XS2 *

```

```

*-----*
***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*

EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

*-----*
* Starting To Process Header Record XS3 *
*-----*

XS XS3 600.0 * * * 0.0015

*** Completed Reading Data Associated With Header Record XS3 ***
*** No Roughness Data Input, Propagating From Previous Section ***
*** Storing X-Section Data In Temporary File As Record Number 3 ***

*** Data Summary For Header Record XS3 ***
SRD Location: 600. Cross-Section Skew: .0 Error Code 0
Valley Slope: .00150 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (14 pairs)

```

X	Y	X	Y	X	Y
-27.432	141.507	.000	140.288	13.717	139.313
30.176	139.496	33.529	138.734	45.721	138.581
48.768	137.027	57.303	137.088	64.009	138.551
78.639	138.551	84.125	139.374	104.852	139.374
131.064	140.288	143.256	141.507		

```

-----
Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 141.507 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 141.507 )
Minimum Y-Elevation: 137.027 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 141.507 ( associated X-Station: -27.432 )

Roughness Data ( 5 SubAreas )

```

SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

```

*-----*

```

```

*          Finished Processing Header Record XS3          *
*-----*
***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*

EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

*-----*
*          Starting To Process Header Record XS4          *
*-----*

XS  XS4    750.0

*** Completed Reading Data Associated With Header Record XS4 ***
*** No Roughness Data Input, Propagating From Previous Section ***
*** Storing X-Section Data In Temporary File As Record Number 4 ***

*** Data Summary For Header Record XS4 ***
SRD Location:      750. Cross-Section Skew:    .0 Error Code  0
Valley Slope:     .00150 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion:    .50 Contraction:    .00

          X,Y-coordinates (14 pairs)
          X           Y           X           Y           X           Y
-----
-27.432    141.732      .000     140.513      13.717     139.538
 30.176    139.721     33.529     138.959      45.721     138.806
 48.768    137.252     57.303     137.313      64.009     138.776
 78.639    138.776     84.125     139.599     104.852     139.599
131.064    140.513     143.256     141.732
-----

          Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 141.732 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 141.732 )
Minimum Y-Elevation: 137.252 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 141.732 ( associated X-Station: -27.432 )

          Roughness Data ( 5 SubAreas )
          Transition Roughness Hydraulic Horizontal
SubArea    Point    Coefficient    Depth    Breakpoint
-----
    1      Bottom    .070          .305      ---
          Top       .060          .914      ---
          --        ---          ---      30.176
    2      Bottom    .060          .610      ---
          Top       .050          1.524     ---
          --        ---          ---      45.721
    3      Bottom    .045          .000      ---
          Top       .035          .305      ---
          --        ---          ---      64.009
    4      Bottom    .060          .305      ---
          Top       .050          1.219     ---
          --        ---          ---      84.125
    5      Bottom    .070          .305      ---
          Top       .060          .914      ---

```

```

*-----*
*      Finished Processing Header Record XS4      *
*-----*
***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*

EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

*-----*
*      Starting To Process Header Record XS5      *
*-----*

```

XS XS5 900.0

```

*** Completed Reading Data Associated With Header Record XS5 ***
*** No Roughness Data Input, Propagating From Previous Section ***
*** Storing X-Section Data In Temporary File As Record Number 5 ***

```

```

*** Data Summary For Header Record XS5 ***
SRD Location: 900. Cross-Section Skew: .0 Error Code 0
Valley Slope: .00150 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

```

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	141.957	.000	140.738	13.717	139.763
30.176	139.946	33.529	139.184	45.721	139.031
48.768	137.477	57.303	137.538	64.009	139.001
78.639	139.001	84.125	139.824	104.852	139.824
131.064	140.738	143.256	141.957		

```

Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 141.957 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 141.957 )
Minimum Y-Elevation: 137.477 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 141.957 ( associated X-Station: -27.432 )

```

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

```

*-----*
*      Finished Processing Header Record XS5      *
*-----*
***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*

EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

*-----*
*      Starting To Process Header Record XS6      *
*-----*

```

XS XS6 1050.0

```

*** Completed Reading Data Associated With Header Record XS6 ***
*** No Roughness Data Input, Propagating From Previous Section ***
*** Storing X-Section Data In Temporary File As Record Number 6 ***

```

```

*** Data Summary For Header Record XS6 ***
SRD Location: 1050. Cross-Section Skew: .0 Error Code 0
Valley Slope: .00150 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

```

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	142.182	.000	140.963	13.717	139.988
30.176	140.171	33.529	139.409	45.721	139.256
48.768	137.702	57.303	137.763	64.009	139.226
78.639	139.226	84.125	140.049	104.852	140.049
131.064	140.963	143.256	142.182		

```

Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 142.182 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 142.182 )
Minimum Y-Elevation: 137.702 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 142.182 ( associated X-Station: -27.432 )

```

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

```

*-----*
*      Finished Processing Header Record XS6      *
*-----*
***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*

EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS
EX

*=====*
*      Summary of Boundary Condition Information      *
*=====*

#      Reach      Water Surface      Friction
#      Discharge      Elevation      Slope      Flow Regime
--      -----      -
1      84.90      139.056      *****      Sub-Critical
2      127.35      139.385      *****      Sub-Critical
3      169.92      139.629      *****      Sub-Critical
--      -----      -

*=====*
*      Beginning 3 Profile Calculation(s)      *
*=====*

```

***** W S P R O *****

Federal Highway Administration - U. S. Geological Survey

Model for Water-Surface Profile Computations.

Input Units: Metric / Output Units: Metric

EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

<< Beginning Computations for Profile 1 >>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: GAGE	139.056	.112	84.899	78.375	*****	9.945
Header Type: XS	139.168	*****	1.083	2352.43	*****	110.790
SRD: 299.999	138.361	*****	.538	*****	1.881	*****
Section: XS2	139.262	.136	84.899	69.157	149.999	11.257
Header Type: XS	139.399	.218	1.227	2101.53	149.999	108.116
SRD: 449.999	138.659	.012	.616	.0015	1.779	.000
Section: XS3	139.508	.130	84.899	71.218	149.999	10.958
Header Type: XS	139.639	.238	1.192	2156.04	149.999	108.726
SRD: 599.999	138.884	.000	.599	.0016	1.806	.006
Section: XS4	139.743	.128	84.899	72.121	149.999	10.827
Header Type: XS	139.871	.230	1.177	2180.33	149.999	108.986
SRD: 749.999	139.111	.000	.591	.0015	1.817	.006
Section: XS5	139.972	.127	84.899	72.506	149.999	10.773
Header Type: XS	140.099	.226	1.170	2190.66	149.999	109.102
SRD: 899.999	139.336	.000	.588	.0015	1.821	.005
Section: XS6	140.198	.126	84.899	72.682	149.999	10.749
Header Type: XS	140.325	.224	1.168	2195.43	149.999	109.152
SRD: 1049.999	139.561	.000	.586	.0015	1.823	.005

<< Completed Computations of Profile 1 >>

***** W S P R O *****

Federal Highway Administration - U. S. Geological Survey

Model for Water-Surface Profile Computations.

Input Units: Metric / Output Units: Metric

EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

<< Beginning Computations for Profile 2 >>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: GAGE	139.385	.129	127.350	113.867	*****	5.317
Header Type: XS	139.514	*****	1.118	3442.19	*****	120.224
SRD: 299.999	138.682	*****	.511	*****	2.032	*****
Section: XS2	139.599	.153	127.350	104.154	149.999	6.525
Header Type: XS	139.752	.225	1.222	3127.55	149.999	117.761
SRD: 449.999	138.982	.011	.573	.0015	2.013	.000
Section: XS3	139.849	.145	127.350	106.969	149.999	6.170
Header Type: XS	139.995	.241	1.190	3218.41	149.999	118.486
SRD: 599.999	139.209	.000	.554	.0016	2.019	.003
Section: XS4	140.082	.143	127.350	107.936	149.999	6.048
Header Type: XS	140.226	.232	1.179	3249.93	149.999	118.731
SRD: 749.999	139.432	.000	.547	.0016	2.020	-.005
Section: XS5	140.313	.141	127.350	108.542	149.999	5.972
Header Type: XS	140.455	.228	1.173	3269.58	149.999	118.888
SRD: 899.999	139.659	.000	.543	.0015	2.021	.000
Section: XS6	140.541	.141	127.350	108.887	149.999	5.931
Header Type: XS	140.682	.226	1.169	3280.93	149.999	118.972
SRD: 1049.999	139.884	.000	.541	.0015	2.022	.001

<< Completed Computations of Profile 2 >>

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

 EXAMPLE ONE: SIMPLE UNCONSTRICTED FLOW - METRIC
 FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

<< Beginning Computations for Profile 3 >>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: GAGE	139.629	.147	169.920	143.177	*****	1.884
Header Type: XS	139.776	*****	1.186	4435.71	*****	127.221
SRD: 299.999	139.027	*****	.509	*****	2.058	*****
Section: XS2	139.855	.168	169.920	134.123	149.999	2.913
Header Type: XS	140.024	.237	1.266	4118.97	149.999	125.124
SRD: 449.999	139.331	.010	.554	.0016	2.056	.000
Section: XS3	140.111	.159	169.920	137.900	149.999	2.480
Header Type: XS	140.270	.247	1.232	4250.00	149.999	126.007
SRD: 599.999	139.554	.000	.534	.0016	2.058	-.002
Section: XS4	140.351	.155	169.920	139.780	149.999	2.265
Header Type: XS	140.506	.236	1.215	4315.87	149.999	126.444
SRD: 749.999	139.780	.000	.525	.0016	2.058	.000
Section: XS5	140.585	.152	169.920	140.923	149.999	2.135
Header Type: XS	140.738	.230	1.205	4355.91	149.999	126.710
SRD: 899.999	140.004	.000	.519	.0015	2.058	.004
Section: XS6	140.814	.151	169.920	141.375	149.999	2.087
Header Type: XS	140.966	.227	1.201	4372.00	149.999	126.808
SRD: 1049.999	140.229	.000	.517	.0015	2.058	.001

<< Completed Computations of Profile 3 >>

ER

***** Normal end of WSPRO execution. *****
 ***** Elapsed Time: 0 Minutes 4 Seconds *****

Example Two: Single-Opening Bridge

Problem:

At the same site described in the first example, we wish to analyze the backwater effects of a bridge with a roadway centerline at SRD 750.0. The bridge length between the tops of the abutments will be 30 m; bridge width is 10 m. Abutments, in this case, are vertical (without wingwalls).

Initially, the input for this example closely follows the input for example 1. The template section for SRD 750 and sections XS2, XS3, XS5, and XS6 are unchanged. SRD 750.0 (FULLV), SRD 800.0 (APPR), and SRD 720.0 (EXIT) must be added to the example one data.

The user is familiar with all input coding up to the description of the bridge site; explanation of this section of input follows using the design mode:

The **BR** record is the header for a bridge cross-section. The first entry in this record is a unique cross-section identification code that will be called "BRDGE." The second entry is the SRD of the cross-section.

A **BC** record specifies the bridge chord parameters. The first entry in this record is the elevation of the low chord of the bridge deck.

The **BL** record specifies the bridge length and the abutment constraints. The first entry for this example is a default value (blank or zero). This indicates that the bridge length is centered at the mid-point of the horizontal stations controlling the opening. The second entry in this record is the length of the bridge between the top of the abutments. The third entry gives the right-most horizontal location of the left boundary of the proposed opening; the fourth entry gives the left-most location of the right boundary of the proposed opening.

The purpose of a **CD** record is to specify parameters used to compute the flow length and the coefficient of discharge for a bridge. The first of seven entries specifies the bridge opening type; a **1** indicates vertical embankments and vertical abutments, with or without wingwalls. The second entry specifies the total width of the bridge deck in the direction of flow. Entries three through seven are not coded since defaults are used. Entry three describes the embankment side slope and the fourth entry codes the embankment elevation. Entries three and four are not applicable to a type 1 opening. Entry five is the wingwall angle--for this example, the default value of 0 degrees is used. Wingwall width is the sixth entry; we will use the default value 0 ft for the example case. The seventh, and final **CD** entry gives the radius of the entrance rounding. Since we do not have a rounded entrance, the default value of 0 ft is used.

Finally, the Manning's roughness values for the bridge surface are given. The parameters are the same as discussed earlier.

Execution Commands:

Finally, the user codes the **EX** and **ER** records, indicating the start of calculation and end of run, respectively.

Input File: WSPRO2.WSP

```
*F
SI 1
T1      Example Two:  Metric Single Bridge Opening - Component Mode
T2      FHWA Model for Water Surface Profile Computations
*
Q        84.90      127.35      169.92
WS       139.056    139.385    139.629
*
XT  SURVY 300.0
GR       -27.432, 140.982      0.000, 139.763      13.717, 138.788
          30.176, 138.971      33.529, 138.209      45.721, 138.056
          48.768, 136.502      57.303, 136.563      64.009, 138.026
          78.639, 138.026      84.125, 138.849      104.852, 138.849
          131.064, 139.763      143.256, 140.982
*
XS  GAGE 300.0 * 0.5 0.1
N       0.070, 0.060      0.060, 0.050      0.045, 0.035
N       0.060, 0.050      0.070, 0.060
ND      0.305, 0.914      0.610, 1.524      0.000, 0.305
ND      0.305, 1.219      0.305, 0.9144
SA      30.176      45.721      64.009      84.125
*
XS  XS2 450.0 * * * 0.002
XS  XS3 600.0 * * * 0.0012
XS  EXIT 720.0
XS  FULV 750.0
*
BR  BRDG 750.0
BL 0      30      45      65
BC      141.0
CD      1      10.0
*
XS  APPR 800.0
*
XS  XS5 900.0
XS  XS6 1050.0
*
EX
ER
```

Discussion of output:

The input echo section of the output is very similar to that described in example 1 until the bridge section is echoed. A detailed explanation of the bridge and approach sections follow.

Bridge Section:

As with the cross-sections in example 1, the coded input is echoed and the cross-section is processed and summarized. The cross-section information is summarized first. The skew angle, friction slope, valley slope, expansion and contraction coefficient values were initially input at cross-section "exit" SRD 720.0 and remain unchanged for the reach until a new value is coded in. The x,y - coordinate pairs are computed and displayed. X-Y maximum and minimum points are found and the roughness depths and Manning's coefficients are listed. Finally, the bridge parameters, design data and pier data (input in records **BR**, **BC**, **BL** and **CD**) are echoed.

Approach Section:

The input echo for an approach station closely follows the format of a standard cross-section. The only "new" information is the bridge projection data, which is coded in the **BP** record. Since the approach is unskewed, default values are indicated. The input echo for the approach section is displayed.

Profile Calculations:

Upon completion of the input echoing and data summary, the model computes a water-surface profile for each discharge. The profile for a discharge of 139.056 m³/s is presented below.

The user may notice that the format is the same as the format encountered in example one. The flow which is now constricted, through addition of the single-opening bridge, requires additional descriptors for computational results.

Comparison of the results for unconstricted flow and constricted flow at SRD 750.0 point out the effects of constricting the channel: area is lessened; cross-section total conveyance is lessened; velocity head increased (the alpha velocity head correction factor decreased); friction loss increased; a critical water-surface elevation is indicated; and velocity increased.

Comparing the elevations at the approach section illustrates the effect of backwater occurrence resulting from the constriction of flow.

Output File: WSPRO2.LST

```
***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Run Date & Time: 10/15/97 06:10 am   Version V070197
Input File: WSPRO2.WSP   Output File: WSPRO2.LST
*-----*
*F
***                               Input Data In Free Format                               ***

SI  1

Metric (SI) Units Used in WSPRO

      Quantity      SI Unit      Precision
-----
Length      meters      0.001
Depth       meters      0.001
Elevation   meters      0.001
Widths      meters      0.001

Velocity    meters/second  0.001
Discharge   cubic meters/second  0.001
Slope       meter/meter   0.001

Angles      degrees      0.01
-----

T1          EXAMPLE TWO:  METRIC SINGLE BRIDGE OPENING - COMPONENT MODE
T2          FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS
Q           84.90      127.35      169.92

*** Processing Flow Data; Placing Information into Sequence  1 ***

WS          139.056   139.385   139.629
```

```

***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric

```

```

*-----*

```

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

```

*-----*
* Starting To Process Header Record SURVY *
*-----*

```

```

XT SURVY 300.0
GR      -27.432, 140.982      0.000, 139.763      13.717, 138.788
GR      30.176, 138.971      33.529, 138.209      45.721, 138.056
GR      48.768, 136.502      57.303, 136.563      64.009, 138.026
GR      78.639, 138.026      84.125, 138.849     104.852, 138.849
GR      131.064, 139.763     143.256, 140.982

```

```

*** Completed Reading Data Associated With Header Record SURVY ***
*** Storing Template Header Record Data In Memory ***

```

```

*** Data Summary For Header Record SURVY ***
SRD Location:      300. Valley Slope: ***** Error Code 0

```

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	140.982	.000	139.763	13.717	138.788
30.176	138.971	33.529	138.209	45.721	138.056
48.768	136.502	57.303	136.563	64.009	138.026
78.639	138.026	84.125	138.849	104.852	138.849
131.064	139.763	143.256	140.982		

```

Minimum and Maximum X,Y-coordinates
Minimum X-Station:      -27.432 ( associated Y-Elevation: 140.982 )
Maximum X-Station:      143.256 ( associated Y-Elevation: 140.982 )
Minimum Y-Elevation:     136.502 ( associated X-Station: 48.768 )
Maximum Y-Elevation:     140.982 ( associated X-Station: -27.432 )

```

```

*-----*
* Finished Processing Header Record SURVY *
*-----*

```

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

 * Starting To Process Header Record GAGE *

XS GAGE 300.0 * 0.5 0.1
 N 0.070, 0.060 0.060, 0.050 0.045, 0.035
 N 0.060, 0.050 0.070, 0.060
 ND 0.305, 0.914 0.610, 1.524 0.000, 0.305
 ND 0.305, 1.219 0.305, 0.9144
 SA 30.176 45.721 64.009 84.125

*** Completed Reading Data Associated With Header Record GAGE ***
 *** Storing X-Section Data In Temporary File As Record Number 1 ***

*** Data Summary For Header Record GAGE ***
 SRD Location: 300. Cross-Section Skew: .0 Error Code 0
 Valley Slope: .00000 Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients -> Expansion: .50 Contraction: .10

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	140.982	.000	139.763	13.717	138.788
30.176	138.971	33.529	138.209	45.721	138.056
48.768	136.502	57.303	136.563	64.009	138.026
78.639	138.026	84.125	138.849	104.852	138.849
131.064	139.763	143.256	140.982		

Minimum and Maximum X,Y-coordinates
 Minimum X-Station: -27.432 (associated Y-Elevation: 140.982)
 Maximum X-Station: 143.256 (associated Y-Elevation: 140.982)
 Minimum Y-Elevation: 136.502 (associated X-Station: 48.768)
 Maximum Y-Elevation: 140.982 (associated X-Station: -27.432)

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---

	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

```

*-----*
*      Finished Processing Header Record GAGE      *
*-----*

```

```
***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
```

```
*-----*
```

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

```
*-----*
* Starting To Process Header Record XS2 *
*-----*
```

XS XS2 450.0 * * * 0.002

```
*** Completed Reading Data Associated With Header Record XS2 ***
*** No Roughness Data Input, Propagating From Previous Section ***
*** Storing X-Section Data In Temporary File As Record Number 2 ***
```

```
*** Data Summary For Header Record XS2 ***
SRD Location: 450. Cross-Section Skew: .0 Error Code 0
Valley Slope: .00200 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00
```

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	141.282	.000	140.063	13.717	139.088
30.176	139.271	33.529	138.509	45.721	138.356
48.768	136.802	57.303	136.863	64.009	138.326
78.639	138.326	84.125	139.149	104.852	139.149
131.064	140.063	143.256	141.282		

```
Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 141.282 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 141.282 )
Minimum Y-Elevation: 136.802 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 141.282 ( associated X-Station: -27.432 )
```

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

* Finished Processing Header Record XS2 *

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

 * Starting To Process Header Record XS3 *

XS XS3 600.0 * * * 0.0012

*** Completed Reading Data Associated With Header Record XS3 ***
 *** No Roughness Data Input, Propagating From Previous Section ***
 *** Storing X-Section Data In Temporary File As Record Number 3 ***

*** Data Summary For Header Record XS3 ***
 SRD Location: 600. Cross-Section Skew: .0 Error Code 0
 Valley Slope: .00120 Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	141.462	.000	140.243	13.717	139.268
30.176	139.451	33.529	138.689	45.721	138.536
48.768	136.982	57.303	137.043	64.009	138.506
78.639	138.506	84.125	139.329	104.852	139.329
131.064	140.243	143.256	141.462		

Minimum and Maximum X,Y-coordinates
 Minimum X-Station: -27.432 (associated Y-Elevation: 141.462)
 Maximum X-Station: 143.256 (associated Y-Elevation: 141.462)
 Minimum Y-Elevation: 136.982 (associated X-Station: 48.768)
 Maximum Y-Elevation: 141.462 (associated X-Station: -27.432)

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

* Finished Processing Header Record XS3 *

```

***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric

```

```

*-----*

```

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

```

*-----*
* Starting To Process Header Record EXIT *
*-----*

```

XS EXIT 720.0

```

*** Completed Reading Data Associated With Header Record EXIT ***
*** No Roughness Data Input, Propagating From Previous Section ***
*** Storing X-Section Data In Temporary File As Record Number 4 ***

```

```

*** Data Summary For Header Record EXIT ***
SRD Location: 720. Cross-Section Skew: .0 Error Code 0
Valley Slope: .00120 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

```

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	141.606	.000	140.387	13.717	139.412
30.176	139.595	33.529	138.833	45.721	138.680
48.768	137.126	57.303	137.187	64.009	138.650
78.639	138.650	84.125	139.473	104.852	139.473
131.064	140.387	143.256	141.606		

```

Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 141.606 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 141.606 )
Minimum Y-Elevation: 137.126 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 141.606 ( associated X-Station: -27.432 )

```

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

```
*-----*
*      Finished Processing Header Record EXIT      *
*-----*
```

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

 * Starting To Process Header Record FULV *

XS FULV 750.0

*** Completed Reading Data Associated With Header Record FULV ***
 *** No Roughness Data Input, Propagating From Previous Section ***
 *** Storing X-Section Data In Temporary File As Record Number 5 ***

*** Data Summary For Header Record FULV ***
 SRD Location: 750. Cross-Section Skew: .0 Error Code 0
 Valley Slope: .00120 Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	141.642	.000	140.423	13.717	139.448
30.176	139.631	33.529	138.869	45.721	138.716
48.768	137.162	57.303	137.223	64.009	138.686
78.639	138.686	84.125	139.509	104.852	139.509
131.064	140.423	143.256	141.642		

Minimum and Maximum X,Y-coordinates
 Minimum X-Station: -27.432 (associated Y-Elevation: 141.642)
 Maximum X-Station: 143.256 (associated Y-Elevation: 141.642)
 Minimum Y-Elevation: 137.162 (associated X-Station: 48.768)
 Maximum Y-Elevation: 141.642 (associated X-Station: -27.432)

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

* Finished Processing Header Record FULV *

```

***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric
*-----*
EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

*-----*
* Starting To Process Header Record BRDG *
*-----*

BR BRDG 750.0
BL 0 30 45 65
BC 141.0
CD 1 10.0

*** Completed Reading Data Associated With Header Record BRDG ***
*** No Roughness Data Input, Propagating From Previous Section ***
+++072 NOTICE: X-coordinate # 2 increased to eliminate vertical segment.
+++072 NOTICE: X-coordinate # 8 increased to eliminate vertical segment.
*** Storing Bridge Data In Temporary File As Record Number 6 ***

*** Data Summary For Bridge Record BRDG ***
SRD Location: 750. Cross-Section Skew: .0 Error Code 0
Valley Slope: ***** Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates ( 9 pairs)
-----
X Y X Y X Y
-----
40.000 141.000 40.100 138.788 45.721 138.716
48.768 137.162 57.303 137.223 64.009 138.686
70.000 138.686 70.100 141.000 40.000 141.000
-----

Minimum and Maximum X,Y-coordinates
Minimum X-Station: 40.000 ( associated Y-Elevation: 141.000 )
Maximum X-Station: 70.100 ( associated Y-Elevation: 141.000 )
Minimum Y-Elevation: 137.162 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 141.000 ( associated X-Station: 40.000 )

Roughness Data ( 5 SubAreas )
-----
SubArea Transition Roughness Hydraulic Horizontal
Point Coefficient Depth Breakpoint
-----
1 Bottom .070 .305 ---
Top .060 .914 ---
-- --- --- 30.176
2 Bottom .060 .610 ---
Top .050 1.524 ---
-- --- --- 45.721
3 Bottom .045 .000 ---
Top .035 .305 ---
-- --- --- 64.009
4 Bottom .060 .305 ---
Top .050 1.219 ---
-- --- --- 84.125

```

5	Bottom	.070	.305	---
	Top	.060	.914	---

Discharge coefficient parameters

BRTYPE	BRWdth	WWAngl	WWWdth	EntRnd	UserCD
1	10.000	*****	*****	*****	*****

Pressure flow elevations

AVBCEL	PFElev
141.000	141.000

Abutment Parameters

ABSLPL	ABSLPR	XTOELT	YTOELT	XTOERT	YTOERT
*****	*****	40.000	138.788	70.000	138.686

Bridge Length and Bottom Chord component input data

BRLEN	LOCOPT	XCONLT	XCONRT	BCELEV	BCSLP	BCXSTA
30.000	0	45.000	65.000	141.000	.0000	55.000

** No Pier/Pile Data Encountered **

* Finished Processing Header Record BRDG *

```

***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric

```

```

*-----*

```

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

```

*-----*
* Starting To Process Header Record APPR *
*-----*

```

XS APPR 800.0

```

*** Completed Reading Data Associated With Header Record APPR ***
*** No Roughness Data Input, Propagating From Previous Section ***
*** Storing X-Section Data In Temporary File As Record Number 7 ***

```

```

*** Data Summary For Header Record APPR ***
SRD Location:      800. Cross-Section Skew:   .0 Error Code  0
Valley Slope:    .00120 Averaging Conveyance By Geometric Mean.
Energy Loss Coefficients -> Expansion:   .50 Contraction:   .00

```

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	141.702	.000	140.483	13.717	139.508
30.176	139.691	33.529	138.929	45.721	138.776
48.768	137.222	57.303	137.283	64.009	138.746
78.639	138.746	84.125	139.569	104.852	139.569
131.064	140.483	143.256	141.702		

```

Minimum and Maximum X,Y-coordinates
Minimum X-Station: -27.432 ( associated Y-Elevation: 141.702 )
Maximum X-Station: 143.256 ( associated Y-Elevation: 141.702 )
Minimum Y-Elevation: 137.222 ( associated X-Station: 48.768 )
Maximum Y-Elevation: 141.702 ( associated X-Station: -27.432 )

```

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
2	Bottom	.060	.610	---
	Top	.050	1.524	---
3	Bottom	.045	.000	---
	Top	.035	.305	---
4	Bottom	.060	.305	---
	Top	.050	1.219	---
5	Bottom	.070	.305	---
	Top	.060	.914	---

Bridge datum projection(s): XREFLT XREFRT FDSTLT FDSTRT
***** ***** ***** *****

```
*-----*
*      Finished Processing Header Record APPR      *
*-----*
```

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

 * Starting To Process Header Record XS5 *

XS XS5 900.0

*** Completed Reading Data Associated With Header Record XS5 ***
 *** No Roughness Data Input, Propagating From Previous Section ***
 *** Storing X-Section Data In Temporary File As Record Number 8 ***

*** Data Summary For Header Record XS5 ***
 SRD Location: 900. Cross-Section Skew: .0 Error Code 0
 Valley Slope: .00120 Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	141.822	.000	140.603	13.717	139.628
30.176	139.811	33.529	139.049	45.721	138.896
48.768	137.342	57.303	137.403	64.009	138.866
78.639	138.866	84.125	139.689	104.852	139.689
131.064	140.603	143.256	141.822		

Minimum and Maximum X,Y-coordinates
 Minimum X-Station: -27.432 (associated Y-Elevation: 141.822)
 Maximum X-Station: 143.256 (associated Y-Elevation: 141.822)
 Minimum Y-Elevation: 137.342 (associated X-Station: 48.768)
 Maximum Y-Elevation: 141.822 (associated X-Station: -27.432)

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

* Finished Processing Header Record XS5 *

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

 * Starting To Process Header Record XS6 *

XS XS6 1050.0

*** Completed Reading Data Associated With Header Record XS6 ***
 *** No Roughness Data Input, Propagating From Previous Section ***
 *** Storing X-Section Data In Temporary File As Record Number 9 ***

*** Data Summary For Header Record XS6 ***
 SRD Location: 1050. Cross-Section Skew: .0 Error Code 0
 Valley Slope: .00120 Averaging Conveyance By Geometric Mean.
 Energy Loss Coefficients -> Expansion: .50 Contraction: .00

X,Y-coordinates (14 pairs)					
X	Y	X	Y	X	Y
-27.432	142.002	.000	140.783	13.717	139.808
30.176	139.991	33.529	139.229	45.721	139.076
48.768	137.522	57.303	137.583	64.009	139.046
78.639	139.046	84.125	139.869	104.852	139.869
131.064	140.783	143.256	142.002		

Minimum and Maximum X,Y-coordinates
 Minimum X-Station: -27.432 (associated Y-Elevation: 142.002)
 Maximum X-Station: 143.256 (associated Y-Elevation: 142.002)
 Minimum Y-Elevation: 137.522 (associated X-Station: 48.768)
 Maximum Y-Elevation: 142.002 (associated X-Station: -27.432)

Roughness Data (5 SubAreas)				
SubArea	Transition Point	Roughness Coefficient	Hydraulic Depth	Horizontal Breakpoint
1	Bottom	.070	.305	---
	Top	.060	.914	---
	--	---	---	30.176
2	Bottom	.060	.610	---
	Top	.050	1.524	---
	--	---	---	45.721
3	Bottom	.045	.000	---
	Top	.035	.305	---
	--	---	---	64.009
4	Bottom	.060	.305	---
	Top	.050	1.219	---
	--	---	---	84.125
5	Bottom	.070	.305	---
	Top	.060	.914	---

* Finished Processing Header Record XS6 *

```

***** W S P R O *****
Federal Highway Administration - U. S. Geological Survey
Model for Water-Surface Profile Computations.
Input Units: Metric / Output Units: Metric

```

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```

```

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

```

```

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

```

EX

```

*=====*
* Summary of Boundary Condition Information *
*=====*

```

#	Reach Discharge	Water Surface Elevation	Friction Slope	Flow Regime
1	84.90	139.056	*****	Sub-Critical
2	127.35	139.385	*****	Sub-Critical
3	169.92	139.629	*****	Sub-Critical

```

*=====*
* Beginning 3 Profile Calculation(s) *
*=====*

```

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

<< Beginning Computations for Profile 1 >>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: GAGE	139.056	.112	84.899	78.375	*****	9.945
Header Type: XS	139.168	*****	1.083	2352.43	*****	110.790
SRD: 299.999	138.361	*****	.538	*****	1.881	*****
Section: XS2	139.262	.136	84.899	69.157	149.999	11.257
Header Type: XS	139.399	.218	1.227	2101.53	149.999	108.116
SRD: 449.999	138.659	.012	.616	.0015	1.779	.000
Section: XS3	139.506	.119	84.899	75.391	149.999	10.361
Header Type: XS	139.626	.226	1.126	2269.44	149.999	109.937
SRD: 599.999	138.841	.000	.563	.0015	1.852	.000
Section: EXIT	139.676	.113	84.899	78.003	120.000	9.997
Header Type: XS	139.789	.162	1.088	2342.00	120.000	110.684
SRD: 720.000	138.983	.000	.541	.0014	1.877	.003
Section: FULV	139.716	.112	84.899	78.459	29.999	9.933
Header Type: FV	139.829	.039	1.082	2354.79	29.999	110.814
SRD: 749.999	139.021	.000	.537	.0013	1.881	.001

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

Section: APPR	139.782	.110	84.899	79.075	49.999	9.848
Header Type: AS	139.893	.064	1.073	2372.12	49.999	110.989
SRD: 799.999	139.079	.000	.533	.0013	1.887	.001

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

<<< The Following Data Reflect The "Constricted" Profile >>>

<<< Beginning Bridge/Culvert Hydraulic Computations >>>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: BRDG	139.667	.190	84.899	48.948	29.999	40.060
Header Type: BR	139.857	.048	1.734	1904.08	29.999	70.042
SRD: 749.999	138.958	.019	.433	*****	1.239	-.001

Specific Bridge Information	C	P/A	PFELEV	BLN	XLAB	XRAB
Bridge Type 1 Flow Type 1	-----	-----	-----	-----	-----	-----
Pier/Pile Code **	.8984	.000	140.999	29.999	39.999	69.999

Unconstricted Full Valley Section Water Surface Elevation: 139.716
 Downstream Bridge Section Water Surface Elevation: 139.667
 Bridge DrawDown Distance: .049

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	139.840	.098	84.899	84.952	40.000	9.040
Header Type: AS	139.938	.061	.999	2540.47	41.135	112.635
SRD: 799.999	139.079	.019	.490	.0013	1.932	.002

** Change in Approach Section Water Surface Elevation: .058 **

Approach Section APPR Flow Contraction Information					
M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.704	.161	2129.5	40.508	70.490	139.840

<<< End of Bridge Hydraulics Computations >>>

Section: XS5	139.952	.099	84.899	84.185	99.999	9.143
Header Type: XS	140.052	.112	1.008	2518.18	99.999	112.425
SRD: 899.999	139.199	.000	.495	.0011	1.926	.003
Section: XS6	140.124	.101	84.899	83.311	149.999	9.263
Header Type: XS	140.226	.172	1.019	2492.92	149.999	112.181
SRD: 1049.999	139.381	.000	.501	.0011	1.920	.000

<< Completed Computations of Profile 1 >>

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

<< Beginning Computations for Profile 2 >>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: GAGE	139.385	.129	127.350	113.867	*****	5.317
Header Type: XS	139.514	*****	1.118	3442.19	*****	120.224
SRD: 299.999	138.682	*****	.511	*****	2.032	*****
Section: XS2	139.599	.153	127.350	104.154	149.999	6.525
Header Type: XS	139.752	.225	1.222	3127.55	149.999	117.761
SRD: 449.999	138.982	.011	.573	.0015	2.013	.000
Section: XS3	139.848	.133	127.350	111.986	149.999	5.544
Header Type: XS	139.982	.230	1.137	3381.63	149.999	119.757
SRD: 599.999	139.162	.000	.522	.0015	2.027	-.001
Section: EXIT	140.021	.126	127.350	115.357	120.000	5.135
Header Type: XS	140.148	.164	1.103	3490.45	120.000	120.596
SRD: 720.000	139.308	.000	.503	.0014	2.035	.004
Section: FULV	140.064	.124	127.350	116.155	29.999	5.038
Header Type: FV	140.189	.039	1.096	3516.36	29.999	120.794
SRD: 749.999	139.344	.000	.499	.0013	2.036	.005

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

Section: APPR	140.132	.123	127.350	117.083	49.999	4.925
Header Type: AS	140.255	.065	1.087	3546.62	49.999	121.023
SRD: 799.999	139.404	.000	.494	.0013	2.038	.004

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

<<< The Following Data Reflect The "Constricted" Profile >>>

<<< Beginning Bridge/Culvert Hydraulic Computations >>>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: BRDG	139.955	.337	127.350	57.583	29.999	40.047
Header Type: BR	140.293	.057	2.211	2428.58	29.999	70.054
SRD: 749.999	139.328	.087	.510	*****	1.353	-.001

Specific Bridge Information	C	P/A	PFELEV	BLN	XLAB	XRAB
Bridge Type 1 Flow Type 1	-----	-----	-----	-----	-----	-----
Pier/Pile Code **	.8596	.000	140.999	29.999	39.999	69.999

Unconstricted Full Valley Section Water Surface Elevation: 140.064
 Downstream Bridge Section Water Surface Elevation: 139.955
 Bridge DrawDown Distance: .109

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	140.295	.091	127.350	136.495	40.000	2.641
Header Type: AS	140.386	.066	.932	4201.10	41.621	125.678
SRD: 799.999	139.404	.027	.406	.0013	2.057	.004

** Change in Approach Section Water Surface Elevation: .163 **

Approach Section APPR Flow Contraction Information					
M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.741	.273	3052.2	40.741	70.749	140.295

<<< End of Bridge Hydraulics Computations >>>

Section: XS5	140.388	.095	127.350	133.186	99.999	3.018
Header Type: XS	140.484	.094	.956	4086.57	99.999	124.909
SRD: 899.999	139.524	.002	.419	.0009	2.056	.003
Section: XS6	140.535	.101	127.350	129.283	149.999	3.474
Header Type: XS	140.637	.150	.985	3953.16	149.999	123.981
SRD: 1049.999	139.704	.002	.435	.0010	2.054	.000

<< Completed Computations of Profile 2 >>

***** W S P R O *****
 Federal Highway Administration - U. S. Geological Survey
 Model for Water-Surface Profile Computations.
 Input Units: Metric / Output Units: Metric

EXAMPLE TWO: METRIC SINGLE BRIDGE OPENING - COMPONENT MODE

FHWA MODEL FOR WATER SURFACE PROFILE COMPUTATIONS

<< Beginning Computations for Profile 3 >>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: GAGE	139.629	.147	169.920	143.177	*****	1.884
Header Type: XS	139.776	*****	1.186	4435.71	*****	127.221
SRD: 299.999	139.027	*****	.509	*****	2.058	*****
Section: XS2	139.855	.168	169.920	134.123	149.999	2.913
Header Type: XS	140.024	.237	1.266	4118.97	149.999	125.124
SRD: 449.999	139.331	.010	.554	.0016	2.056	.000
Section: XS3	140.113	.146	169.920	143.709	149.999	1.822
Header Type: XS	140.259	.236	1.182	4454.46	149.999	127.348
SRD: 599.999	139.509	.000	.506	.0016	2.058	-.001
Section: EXIT	140.291	.138	169.920	148.010	120.000	1.345
Header Type: XS	140.429	.168	1.148	4608.31	120.000	128.320
SRD: 720.000	139.655	.000	.487	.0014	2.056	.002
Section: FULV	140.333	.136	169.920	148.857	29.999	1.252
Header Type: FV	140.470	.040	1.141	4638.80	29.999	128.511
SRD: 749.999	139.689	.000	.483	.0014	2.056	.002

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

Section: APPR	140.402	.134	169.920	149.929	49.999	1.133
Header Type: AS	140.537	.066	1.133	4677.53	49.999	128.752
SRD: 799.999	139.749	.000	.479	.0013	2.056	.000

<<< The Preceding Data Reflect The "Unconstricted" Profile >>>

<<< The Following Data Reflect The "Constricted" Profile >>>

<<< Beginning Bridge/Culvert Hydraulic Computations >>>

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: BRDG	140.168	.503	169.920	63.973	29.999	40.037
Header Type: BR	140.671	.066	2.656	2847.24	29.999	70.063
SRD: 749.999	139.641	.175	.581	*****	1.399	-.001

Specific Bridge Information	C	P/A	PFELEV	BLN	XLAB	XRAB
Bridge Type 1 Flow Type 1	-----	-----	-----	-----	-----	-----
Pier/Pile Code **	.8456	.000	140.999	29.999	39.999	69.999

Unconstricted Full Valley Section Water Surface Elevation: 140.333
 Downstream Bridge Section Water Surface Elevation: 140.168
 Bridge DrawDown Distance: .165

	WSEL EGEL CRWS	VHD HF HO	Q V FR #	AREA K SF	SRDL FLEN ALPHA	LEW REW ERR
Section: APPR	140.693	.083	169.920	188.608	40.000	-4.728
Header Type: AS	140.776	.069	.900	6136.91	42.169	133.165
SRD: 799.999	139.749	.035	.350	.0013	2.020	.004

** Change in Approach Section Water Surface Elevation: .291 **

Approach Section APPR Flow Contraction Information					
M(G)	M(K)	KQ	XLKQ	XRKQ	OTEL
.765	.354	3959.7	40.862	70.889	140.693

<<< End of Bridge Hydraulics Computations >>>

Section: XS5	140.769	.089	169.920	182.664	99.999	-3.758
Header Type: XS	140.859	.079	.930	5902.75	99.999	132.733
SRD: 899.999	139.869	.002	.366	.0008	2.028	.000
Section: XS6	140.896	.097	169.920	175.445	149.999	-2.556
Header Type: XS	140.993	.130	.968	5623.83	149.999	132.199
SRD: 1049.999	140.050	.003	.387	.0009	2.037	.001

<< Completed Computations of Profile 3 >>

ER

***** Normal end of WSPRO execution. *****
 ***** Elapsed Time: 0 Minutes 9 Seconds *****

APPENDIX B: FOOTPRINTS FOR TYPICAL APPLICATIONS

This section presents two basic WSPRO applications represented by an arrangement of command strings. These arrangements of command strings, or footprints, are provided for the following typical applications:

1. Unconstricted water-surface profile.
2. Single-opening bridge (design mode).

These two footprints are contained in files on the HYDRAIN package diskettes. These files are comprised of command lines with empty data fields for which the user can supply the appropriate data (the footprint files should be copied and renamed before any editing is done.)

1. Unconstricted Water-Surface Profile

Filename: UNC~FP.WSP

The following command string is a typical footprint of an unconstricted water-surface profile model:

```
* --->Unconstricted Channel Water-Surface Profile
* --->REMOVE all unused command lines
* ---> OPTIONAL---First command, *F switches to free data format
*F
* ---> OPTIONAL---<T1, T2, and T3> commands
T1
T2
T3
*
* ---> OPTIONAL---J1 AND UT commands
J1
UT
*
* ---> Initial Flow Conditions:  CHOOSE <Q and WS> or <Q and SK>
Q
WS
SK
*
* ---> Channel (most downstream) Cross-section
XS
GR
* ---> ONLY N command is REQUIRED for Roughness Data
N
* ---> Use SA and ND as appropriate
SA
ND
*
```

```

* ---> Next upstream channel cross-section
XS
* ---> UPDATE GR, N, SA, and ND commands ONLY if their parameters have changed
*       from the previous channel cross-section
GR
N
SA
ND
* ---> OPTIONAL---FL command
FL
*
* ---> FOR ADDITIONAL Cross-sections: Repeat the sequence of commands
*       (XS, GR, N, SA, ND, FL) as shown in preceding cross-section
*
EX
* ---> Either the ER or END command can be used to indicate end of run
ER

```

2. Single-Opening Bridge--Design Mode

Filename: BRDES~FP.WSP

The following command string is a typical footprint of a single-opening bridge model for the design mode:

```

* --->Single Opening Bridge (DESIGN)
* --->REMOVE all unused command lines
* ---> OPTIONAL---First command, *F switches to free data format
*F
* ---> OPTIONAL---T1, T2, and T3 commands
T1
T2
T3
*
* ---> OPTIONAL---J1 AND UT commands
J1
UT
*
* ---> Initial Flow Conditions: CHOOSE <Q and WS> or <Q and SK>
Q
WS
SK
*
* ---> EXIT Channel Cross-section
XS
GR
* ---> ONLY N command is REQUIRED for Roughness Data
N
* ---> Use SA and ND as appropriate
SA
ND
*
* ---> FULL VALLEY Channel Cross-section
XS

```

```

* ---> UPDATE GR, N, SA, and ND commands ONLY if parameters have changed
* ---> from the previous (EXIT) cross-section.
GR
N
SA
ND
* ---> OPTIONAL---FL command
FL
*
* ---> BRIDGE Cross-section (design mode)
BR
BC
BL
CD
* ---> AB command REQUIRED for a Type 3 Opening ONLY
AB
* ---> OPTIONAL---KD command---REQUIRED ONLY to override the default
* position of the KQ-section
KD
* ---> OPTIONAL---PIER or PILE Data---PD command
PD
* ---> UPDATE N, SA, and ND commands ONLY if parameters have changed
* from the previous (FULL VALLEY) cross-section
N
SA
ND
*
* ---> OPTIONAL---GUIDE BANK Data---GB and GR commands
GB
* ---> OPTIONAL---GR command
GR
* ---> UPDATE N, SA, and ND commands ONLY if parameters have changed
* from the previous (BRIDGE) cross-section
N
SA
ND
*
* ---> OPTIONAL---ROAD GRADE Data---XR, GR or RG, and BP commands
XR
* ---> CHOOSE <GR> or <RG>
GR
RG
* ---> OPTIONAL---BP command
BP
* ---> UPDATE N, SA, and ND commands ONLY if their parameters have changed
* from the previous (FULL VALLEY) cross-section
N
SA
ND
*
* ---> APPROACH Channel Cross-section
AS
* ---> UPDATE GR command ONLY if its parameters have changed from the
* previous (FULL VALLEY) cross-section

```

GR
* ---> UPDATE N, SA, and ND commands ONLY if parameters have changed from
* the previous (ROAD GRADE or FULL VALLEY) cross-section
N
SA
ND
* ---> OPTIONAL---FL command
FL
*
EX
* ---> The ER command is used to indicate end of run
ER

APPENDIX C: WSPRO COMMANDS

This appendix details the meaning and syntax of each command available in WSPRO. The descriptions are ordered alphabetically and include information on the command name, its purpose, and its structure. Any important notes pertaining to the command are also included.

COMMAND AB - AButment parameters

Purpose: To specify abutment slopes (ONLY for Type 3 opening in DESIGN MODE) or abutment toe elevations (ONLY for Type 2 openings for FIXED-GEOMETRY MODE).

Structure:

AB abslpl [abslpr]

-- OR --

AB yablt [yabrt]

- 1) abslpl - slope of left abutment. Required only for Type 3 opening COMPONENT MODE.
- 2) abslpr - slope of right abutment. Required only for Type 3 opening COMPONENT MODE. (Note: this parameter not required if same as abslpl.)

-- OR --

- 1) yablt - toe elevation at left abutment. Required only for Type 2 opening in COORDINATE MODE.
- 2) yabrt - toe elevation at right abutment. Required only for Type 2 opening in COORDINATE MODE. (Note: this parameter not required if same as yablt). See CD command for explanation of these parameters.

COMMAND AS - Approach Section

Purpose: To reference approach cross-section.

Structure:

AS secid [srd, skew, ek, ck, vslope]

- 1) secid - unique cross-section identification code.
- 2) srd - section reference distance. A cumulative distance along the stream measured from any arbitrary zero reference point (srd may be negative).
- 3) skew - the acute angle (degrees) that the cross-section must be rotated to orient it normal to the flow direction. (Default is 0.0 degrees.)
- 4) ek - OPTIONAL - coefficient used for computing expansion losses in the energy equation. (Default value is 0.5.)
- 5) ck - OPTIONAL - coefficient used for computing contraction losses in the energy equation. (Default value is 0.0.)
- 6) vslope - valley slope. Used for adjusting elevations of propagated geometry data. (Default value is either 0.0 or the last valley slope that was input for a previous cross-section.)

COMMAND BC - Bridge deck parameters

Purpose: To specify bridge deck parameters (DESIGN MODE ONLY).

Structure:

BC bcelev [bcslp, bcsta]

- 1) bcelev - low-chord elevation. If bridge deck is not horizontal, bcslp and bcsta are also required.
- 2) bcslp - slope of the bridge deck (negative for left-to-right fall).
- 3) bcsta - x-coordinate corresponding to bcelev.

Note: The above data provides the information necessary to connect the tops of the abutments and the low chord.

COMMAND BL - Bridge Length

Purpose: To specify bridge length and abutment location constraints (DESIGN MODE ONLY).

Structure:

BL locopt, brlen, xconlt, xconrt

- 1) locopt - bridge-location option to specify location of the specified bridge length (brlen) with respect to the specified horizontal stationing (xconlt, xconrt). Three choices are available as follows:
 - 0 - brlen is centered at the midpoint of xconlt and xconrt. This is the default option.
 - 1 - the toe of the right abutment is placed at the location specified by xconrt.
 - 2 - the toe of the left abutment is placed at the location specified by xconlt.
- 2) brlen - the length of the bridge (between the tops of the abutments).
- 3) xconlt - horizontal left station controlling the location of the bridge opening. These always serve as constraints on the abutment locations and bridge length.
- 4) xconrt - horizontal right station controlling right constraint of bridge opening.

Note: If only three parameters are used in this command, locopt defaults to zero.

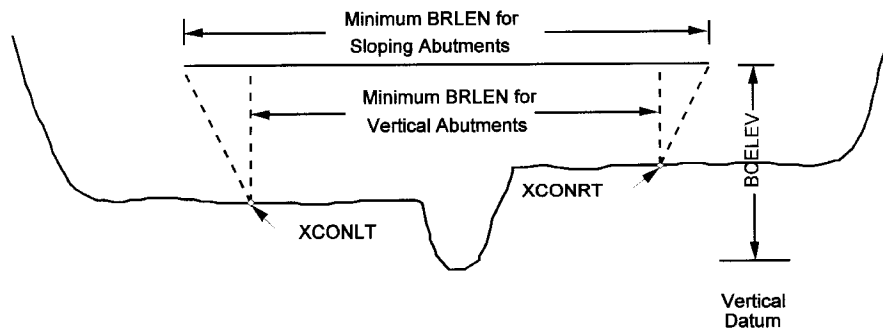
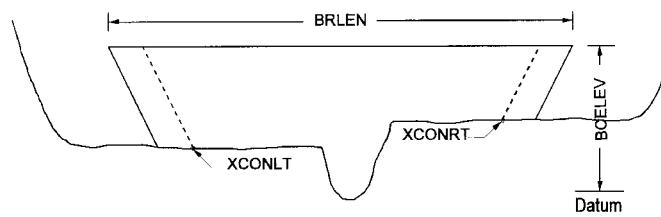
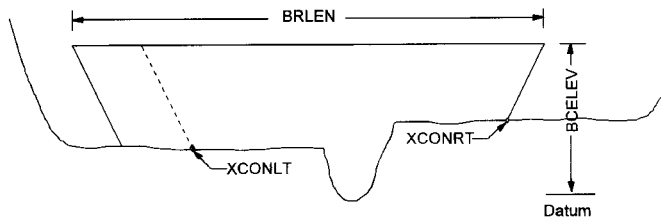


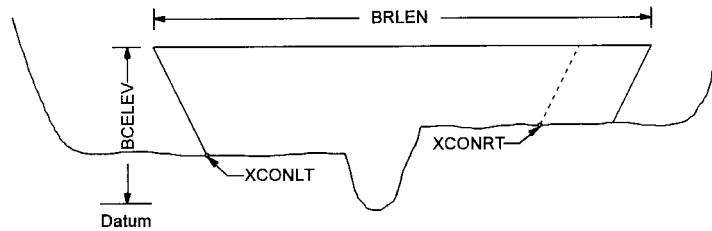
Figure 6. BL command parameters



a) LOC OPT = 0, bridge opening centered at midpoint of tops of abutments



b) LOC OPT = 1, right abutment toe fixed at XCONRT



c) LOC OPT = 2, left abutment toe fixed at XCONLT

Figure 7. Effect of loc opt on bridge opening section command (BL command).

COMMAND BP - Bridge opening

Purpose: To relate bridge opening horizontal datum to the horizontal datum of road and/or approach section(s) (only applicable to single opening situations).

Structure:

BP xreflt [xrefrt, fdstlt, fdstrt]

- 1) xreflt - horizontal station of the road grade or approach section which coincides with the projection of a reference point from the bridge section.
- 2) xrefrt - horizontal station of the approach section which coincides with the projection (parallel to the flow) of a right-hand reference point in the bridge section.
- 3) fdstlt - flow distance measured along the left projection lines.
- 4) fdstrt - flow distance measured along the right projection lines.

Notes:

- 1) The reference points mentioned above are either (1) xconrt and xconlt (from command BL) or (2) minimum and maximum x-coordinates of bridge section.
- 2) The three parameters, xrefrt, fdstlt, and fdstrt, are required to account for channel curvature between bridge and approach cross-sections. The input data for the bridge and approach sections must be aligned normal to the flow.

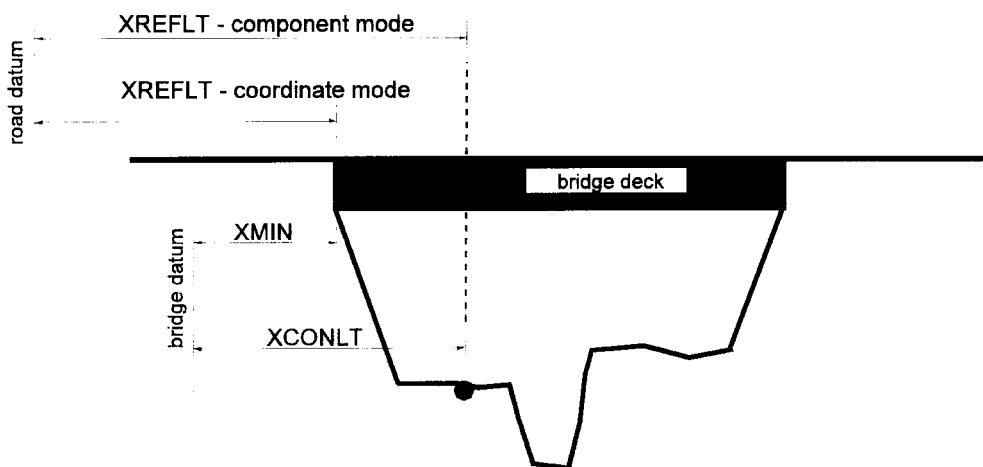


Figure 8. Datum correction between bridge opening and road grade sections.

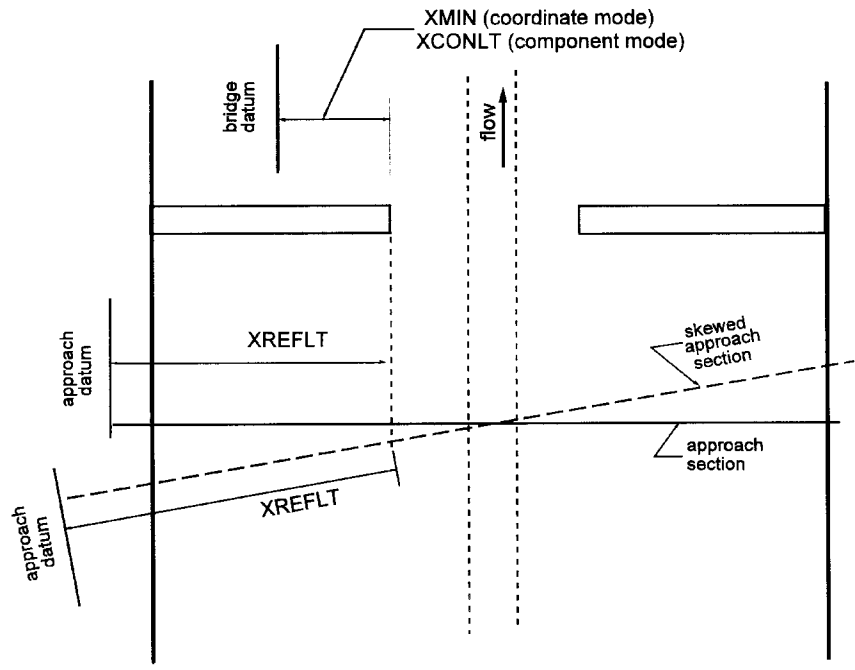


Figure 9. Datum correction between bridge opening and approach sections.

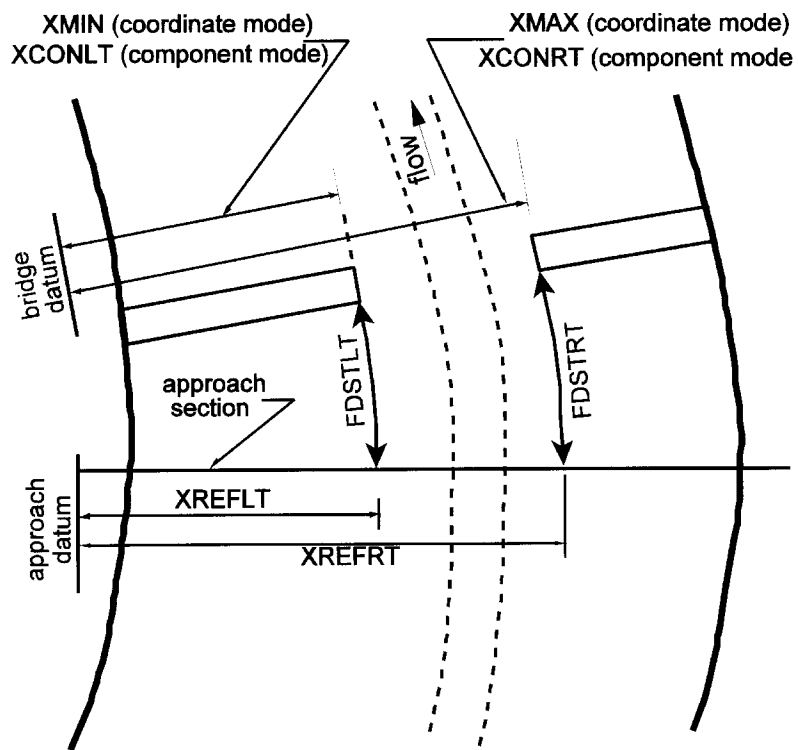


Figure 10. Curvilinear flow between approach and bridge.

COMMAND BR - BRidge section

Purpose: To establish bridge cross-section.

Structure:

BR secid, srd, pfelev, skew, ek, ck, usercd

- 1) secid - unique cross-section identification code.
- 2) srd - section reference distance. Should be assigned the same value as the full valley section.
- 3) pfelev - elevation of the low chord of the bridge opening. (Can be omitted in DESIGN MODE.)
- 4) skew - the acute angle (degrees) that the cross-section must be rotated to orient it normal to the flow direction. (Default is 0.0 degrees.)
- 5) ek - coefficient used for computing expansion losses in the energy equation. (Default value is 0.5.)
- 6) ck - coefficient used for computing contraction losses in the energy equation. (Default value is 0.0.)
- 7) usercd - user-specified coefficient of discharge for a bridge.

COMMAND CC - Culvert Coefficients

Purpose: To assign culvert coefficients. This command is not required if the default values are appropriate.

Structure:

CC ieqno [cke, cvalph, cn]

- 1) ieqno - the inlet equation number.
- 2) cke - the culvert entrance loss coefficient, k_e .
- 3) cvalph - the velocity head coefficient, α , for the culvert.
- 4) cn - Manning's roughness coefficient, n , for the culvert.

Note: Default values for cke, cvalph, and cn are provided on the basis of icode of the CG command.

Table 4. Manning's roughness coefficient, n , and velocity head correction coefficient, α , for culverts.

	Shape	Box	Circle	Arch
Material	n	Velocity Head Correction Coefficient, α		
Concrete	0.012	1.00	1.04	1.05
Corrugated metal	0.035	-	1.12	1.16

COMMAND CD - Coefficient of Discharge

Purpose: To determine the coefficient of discharge for a bridge and the flow length.

Structure:

CD brtype, brwidth, embss, embelv, wwangl, wwwid, entrnd

- 1) brtype - indicates the type of bridge opening, as follows:
 - 1 - vertical embankments and vertical abutments, with or without wingwalls.
 - 2 - sloping embankments and vertical abutments.
 - 3 - sloping embankments and sloping spill through abutments.
 - 4 - sloping embankments and vertical abutments with wingwalls.
- 2) brwidth - total width (in direction of flow) of the bridge deck.
- 3) embss - embankment side slope, expressed in the horizontal change of elevation. (Default value is 0.0) This parameter must be specified for brtype 2, 3, and 4.
- 4) embelv - elevation of top of embankment must be coded for brtype 2, 3, and 4. embel and embss are used to compute the x-component(s) of the flow length through the bridge.
- 5) wwangl - wingwall angle. Required only for type 1 and type 4 openings that have wingwalls. (Default value is 0 degrees.)
- 6) wwwid - wingwall width. Required only for type 1 openings with wingwalls. (Default is 0.0.)
- 7) entrnd - radius of entrance rounding. Required only for type 1 openings with rounded entrance corners. (Default is 0.0.)

COMMAND CD - Coefficient of Discharge (continued)

Notes:

- 1) brtype and brwidth must be coded for all opening types.
- 2) For brtype 1, optional parameters may be applicable as follows:
 - (a) wwangl and wwwid (both parameters must be specified when wingwalls are present).
 - (b) entrnd (if wingwalls are not present and entrance corners are rounded).
 - (c) no optional parameters when neither wingwalls nor entrance rounding exists.
- 3) When coding any of the above optional parameters, embss and embelv should be allowed to default.

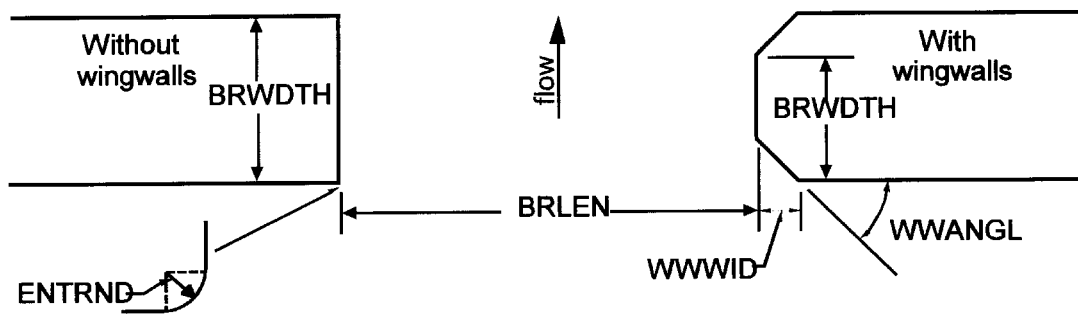
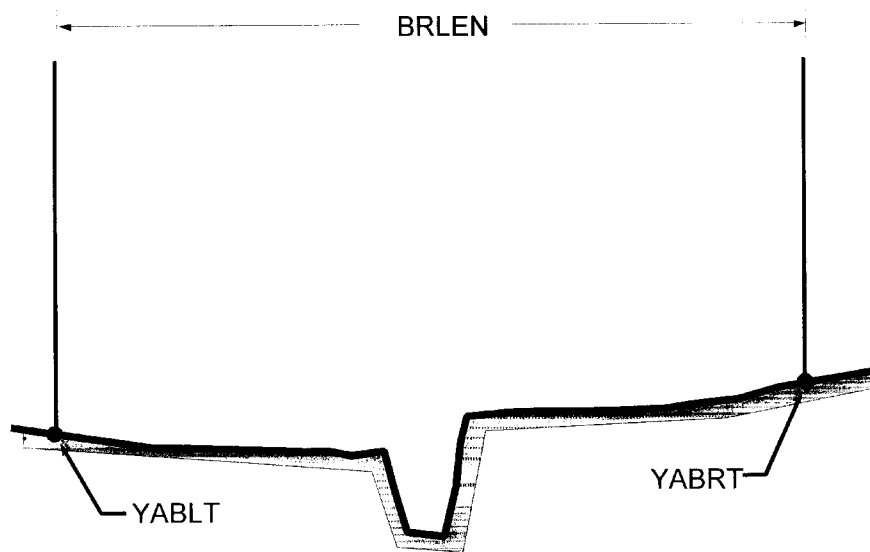
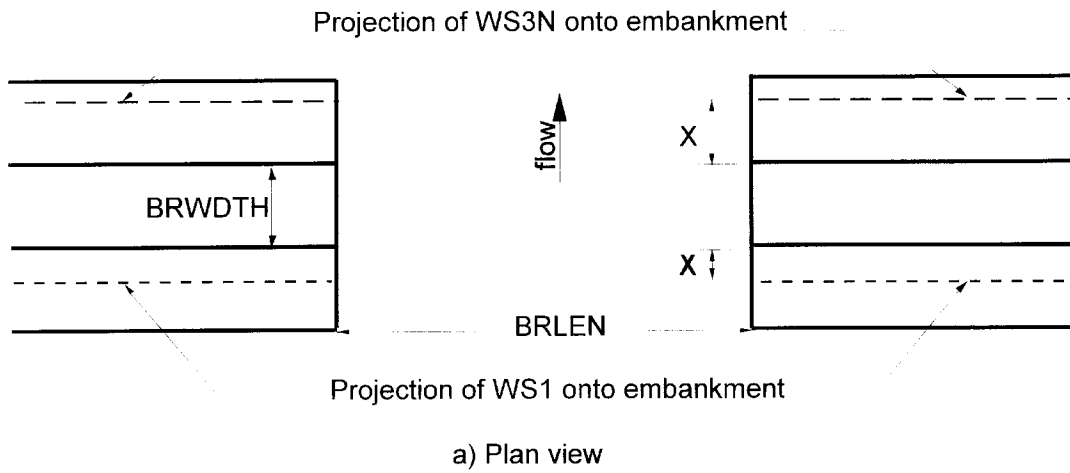
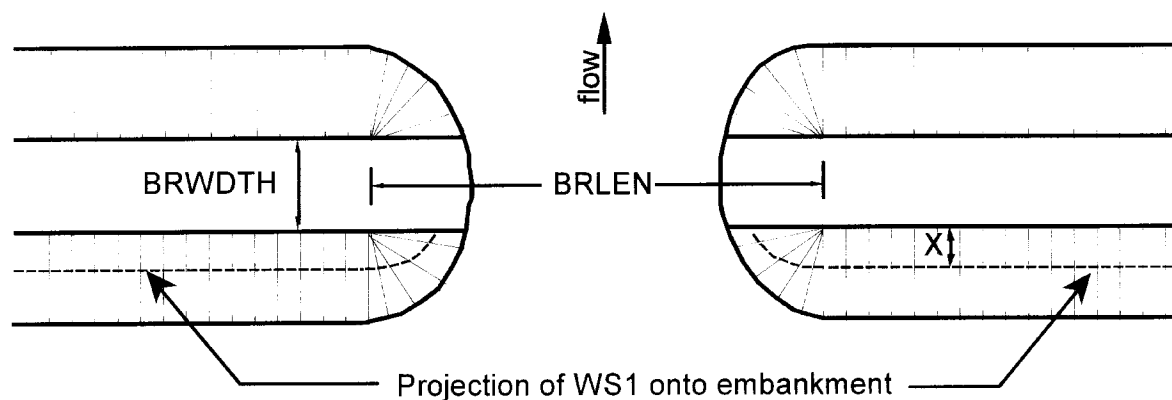


Figure 11. Type 1 bridge opening (br = 1, CD command).

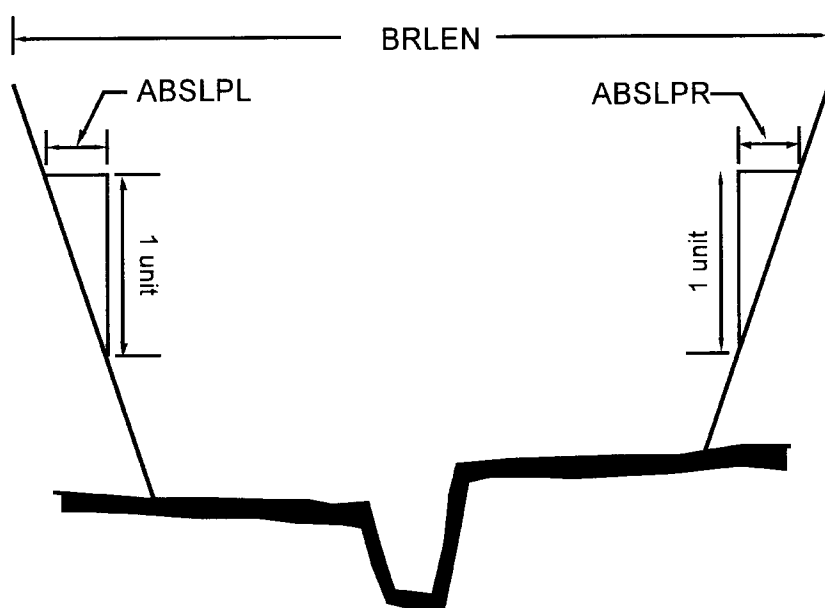


b) Elevation view, upstream side of bridge

Figure 12. Type 2 bridge opening (brtype = 2, CD command).



a) Plan view



b) Elevation view, upstream side of bridge

Figure 13. Type 3 bridge opening (brtype = 3, CD command).

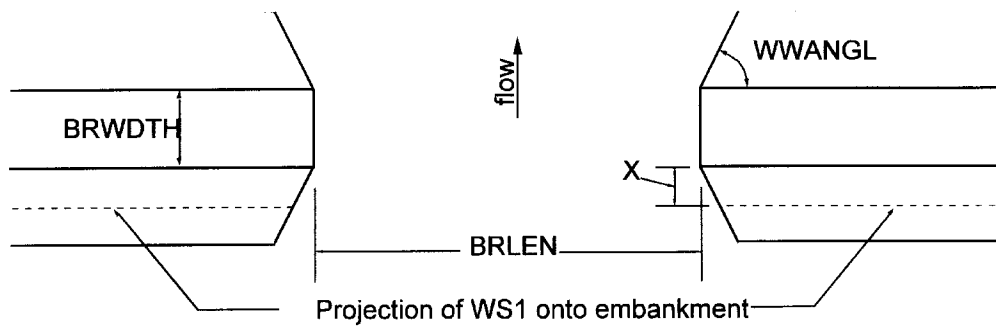


Figure 14. Type 4 bridge opening (brtype = 4, CD command).

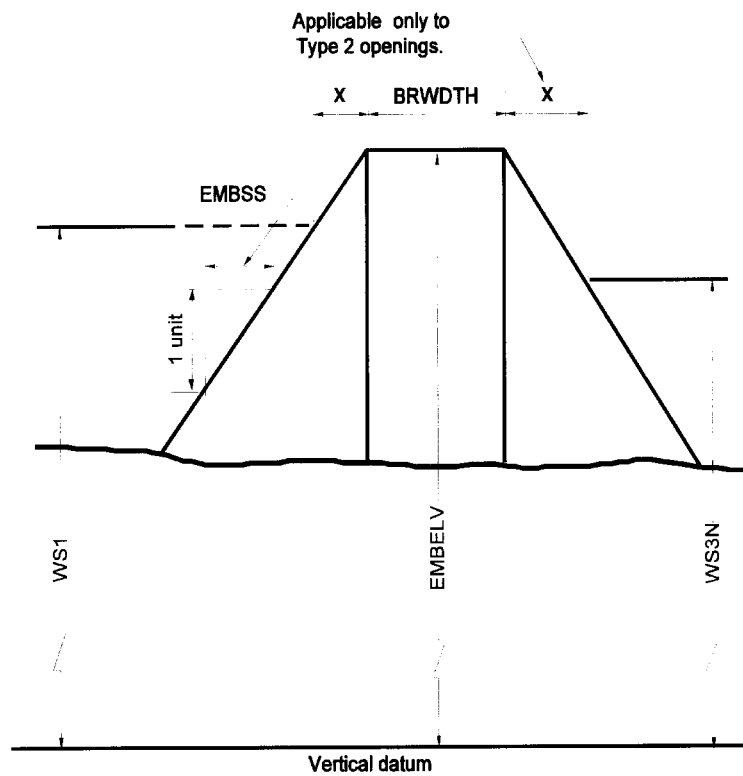


Figure 15. Embankment parameters (brtype 2, 3, and 4, CD command).

COMMAND CG - Culvert section Geometry

Purpose: To establish culvert shape, geometry, material, and inlet type.

Structure:

CG icode, rise, [span, botrad, toprad, corrad]

- 1) icode - three digit culvert code in which the individual digits (e.g., IJK) are interpreted as follows:

I - shape code: 1 = box; 2 = circular; 3 = arch.

J - material code: 1 = concrete; 2 = corrugated metal pipe (steel);
3 = aluminum.

K - inlet control equation code.

- 2) rise - the maximum vertical dimension of the culvert barrel.
3) span - the maximum horizontal dimension of the culvert barrel. Span must be coded for box and pipe-arch culverts but should not be coded for circular culverts.
4) botrad - bottom radius of pipe-arch culvert barrel.
5) toprad - top radius of pipe-arch culvert barrel.
6) corrad - corner radius of pipe-arch culvert barrel.

Notes:

- 1) Caution should be taken in selecting valid icode combinations.
2) If radius parameters are defaulted, approximate values will be computed on basis of icode, span, and rise.

Table 5. Coefficients used in the analysis of culverts (CG command).

I	J	K	Type of inlet ¹	K _e ²
1	1	1	WINGWALLS: 30°-75° flare; square top edge	0.4
1	1	2	HEADWALL: (a) normal or (b) 45° skew; square edge	0.5
1	1	3	WINGWALLS: 15° flare with square edges	0.5
1	1	4	WINGWALLS: extended with 0° flare; square top edge	0.7
1	1	5	HEADWALL: (a) normal of (b) 45° skew; 1:1 bevels	0.2
1	1	6	WINGWALLS: (a) 18° - 33.7° flare with 1½:1 top bevels; or (b) 45° flare with 1:1 top bevel	0.2
1	1	7	HEADWALL: normal with 1½:1 bevel on three sides	0.2
2	1	1	PROJECTING: socket end	0.2
2	1	2	HEADWALL: socket end	0.2
2	1	3	PROJECTING: square edge	0.5
2	1	4	HEADWALL: square edge	0.5
2	1	5	END SECTION	0.5
2	2	5	END SECTION	0.5
2	2	6	BEVEL: 1:1	0.2
2	2	6	BEVEL: 1:1	0.2
2	1	7	BEVEL: 1½:1	0.2
2	2	7	BEVEL: 1½:1	0.2
2	2	1	PROJECTING:	0.9
2	2	2	MITERED:	0.7
2	2	3	HEADWALL:	0.5
3	1	1	HEADWALL: square edge	0.5
3	1	2	HEADWALL: grooved end	0.2
3	1	3	PROJECTING: grooved end	0.2
3	2	1	PROJECTING: CR ³ ≤ 457 mm (18")	0.9
3	2	2	PROJECTING: CR = 787 mm (31")	0.9
3	2	3	PROJECTING: CR = 1194 mm (47")	0.9
3	2	4	MITERED: CR ≤ 457 mm (18")	0.7
3	2	5	MITERED: CR = 787 mm (31")	0.7
3	2	6	MITERED: CR = 1194 mm (47")	0.7
3	3	2	MITERED: CR = 808 mm (31.8")	0.7
3	2	7	HEADWALL: CR ≤ 457 mm (18")	0.5
3	2	8	HEADWALL: CR = 787 mm (31")	0.5
3	2	8	HEADWALL: CR = 787 mm (31")	0.5
3	2	9	HEADWALL: CR = 1194 mm (47")	0.5
3	3	3	HEADWALL: CR = 808 mm (31.8")	0.5

¹ I, J, and K are codes representing shape, material, and inlet type, respectively. The shape code (I) indicates either box (1), circular (2), or arch (3). The material code (J) indicates either concrete (1), corrugated metal (steel) pipe (2), or aluminum (3). The inlet code (K) indicates the inlet conditions described under the Type of inlet column.

² K_e is the culvert entrance-loss coefficient.

³ CR is the corner radius of arch culverts.

COMMAND CV - CulVert cross-section

Purpose: To designate culvert cross-section parameters.

Structure:

CV secid, srd, xctr, cvleng, dsinv, usinv, nbbl

- 1) secid - unique cross-section identification code.
- 2) srd - section reference distance. The srd for the culvert should reflect the location of the downstream end of the barrel and should be the same as the srd of the full-valley cross-section when none of sections are skewed to the flow.
- 3) xctr - horizontal stationing of the center of the culvert measured relative to an arbitrary origin on the left bank. This stationing must be consistent with GR command stationing.
- 4) cvleng - length of the culvert barrel.
- 5) dsinv - elevation of downstream invert (above the common elevation datum).
- 6) usinv - elevation of upstream invert (above the common elevation datum).
- 7) nbbl - number of culvert barrels.

COMMAND DA - Depth of Abutment scour

Purpose: Specifying parameters for the computation of abutment scour.

Structure:

DA secid, [k1, k2, yal, yar, q, fs]

- 1) secid - Unique cross-section identification code. secid is optional (depending on placement in the data stream as with the Q and HP Records).
- 2) k1,k2 - k1 and k2 are the two correction/adjustment factors for abutment shape and embankment skew (default value is 1.0 for both factors).
- 3) yal,yar - A user-specified override for left and right abutment depth in meters, y_a , for cases when an average overbank depth may not be realistic for scour computations (e.g., if the abutment location is within the main channel, some weighted average value of y_a may yield more meaningful estimates of scour depths).
- 4) q - Discharge through the bridge opening (cubic meters per second).
- 5) fs - Factor of safety (default = 1.0).

COMMAND DC - Depth of Contraction scour

Purpose: Specifying parameters to perform live-bed and clear-water contraction scour depth computations.

Structure:

DC	0, secid [bxl, bxr, axl, axr, kl, pw, yb, ya]	(live-bed)
---or---		
dc	1, secid [bxl, bsr, axl, axr, d50, pw, yb, ya]	(clear-water)
1)	secid	- unique cross-section identification code. secid is optional (depending on placement in the data stream as with the q and hp records).
2)	bxl, bxr, axl, axr	- bxl, bxr, axl, axr are the left and right horizontal limits of the bx and ax channel segments, respectively. Defaults for these limits are the main channel top-of-bank stations (input parameters to be added to cross-section header records). ax and bx will be limited, of course, to the difference between left- and right-edges of water. W_2 will be reduced by gross pier width based on pd record input data.
3)	k1	- the k_1 exponent in the contraction scour estimation equation (default 0.59).
4)	pw	- pier width.
5)	yb	- depth of flow in bridge opening.
6)	ya	- depth of flow in channel or floodplain.
7)	d50	- median diameter of bed material in bridge opening or in the floodplain.

Notes:

- (1) Multiple DC records can be used to evaluate different combinations of left and right horizontal limits and/or different values of k_1 .
- (2) It is also possible to add variables yb (water-surface elevation in contracted section), qb (flow through bridge opening), ws1 (water-surface elevation at approach section), qt (total flow at the approach section) to permit contraction scour computations 'divorced' from profile computations.

COMMAND DP - Depth of Pier scour

Purpose: Specifying parameters to perform local pier scour computations.

Structure:

DP	secid [bxl, bxr, pw, yb, qb, k1, k2, k3, v1m, y1m]	
1)	secid	- unique cross-section identification code.
2)	bxl	- left horizontal limit of channel segment to be examined for pier scour computations.
3)	bxr	- right horizontal limit of channel segment to be examined for pier scour computations.
4)	pw	- pier width.
5)	yb	- user-specified override for the water-surface elevation in the bridge opening.
6)	qb	- discharge through the bridge opening.
7)	k1,k2, k3	- correction/adjustment factors applied to the scour estimation equation (default values are 1.1, 1.0, and 1.0).
8)	v1m	- velocity multiplier.
9)	y1m	- depth multiplier.

Notes:

- (1) The v1m and y1m parameters are multipliers to increase or decrease the maximum velocity and depth values. These parameters could be used as safety factors and/or to perform fundamental sensitivity analyses to show variation in scour depth for different combinations of velocity and depth. Multiple DP records can be used to specify different v1m and y1m values for sensitivity analyses.
- (2) Pier scour computations can be divorced from the profile computations by coding the yb and qb parameters. This feature is useful when it is deemed necessary to adjust computed elevations and/or in complex flow situations where water-surface elevations are not determined by WSPRO computations. Velocity and depth values are determined as per the above discussion. These computations could be accomplished by inputting only the bridge section.

COMMAND EF - Effective Flow

Purpose: Allows user to set effective flow limits and user-defined stagnation points.

Structure:

EF xlef, ylef, xref, yref

- 1) ylef - left station.
- 2) ylef - left depth.
- 3) xref - right station.
- 4) yref - right depth.

COMMAND ER - End of Run

Purpose: To signify end of run.

Structure:

ER (no parameters)

Note: Command indicates end of data input; if omitted, harmless error message is generated.

COMMAND EX - EXecutive profile computations

Purpose: To instruct model to begin execution of profile computations and to specify computation direction. **No profiles are computed if EX record is not coded.**

Structure:

EX idir(1), idir(2), ..., idir(nprof)

nx) idir(i) - code indicating computational direction for the ith profile. idir = 0 for upstream computations and idir = 1 for downstream computations. (Can be left blank if all computations are to be done in upstream direction.)

Note: When downstream computations (typically supercritical) are involved, idir should be specified for each discharge on Q command.

COMMAND FL - variable Flow Lengths

Purpose: To specify friction slope averaging technique and/or variable flow length(s) between sections.

Structure:

FL ihfno flen (1) [,xfl(1), flen(2)] [,xfl(2), flen(3)]

- 1) ihfno - code to select the friction slope (or conveyance) averaging technique in the friction loss computations. Valid entries are:
 - 0 - uses geometric mean of conveyance.
 - 1 - uses arithmetic average of conveyance.
 - 2 - uses arithmetic average of friction slope.
 - 3 - uses harmonic mean of friction slope.
- 2) flen - flow length between the current cross-section and the adjacent downstream cross-section. Up to three values may be specified, and these lengths override srd values except in bridge backwater computations. (See figure 16.)
- 3) xfl - x-coordinate of breakpoints between the segments of the cross-section for which multiple flen values are to be applied. One value is necessary if 2 flen values are specified and two values are necessary if 3 flen values are specified. (See figure 16.)

Notes:

- 1) ihfno is propagated from section to section until a different value is introduced.
- 2) ihfno is overridden by ihfnoj if coded on J1 command.

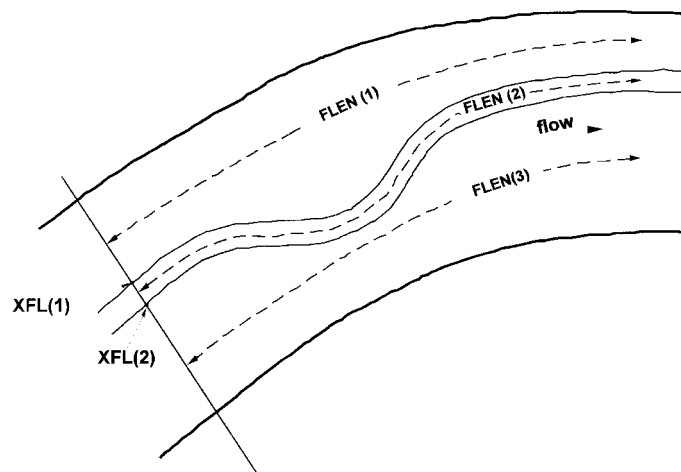


Figure 16. FL command parameters.

COMMAND FS - Floodways global Surcharges

Purpose: Optional record for floodway analysis to specify global surcharges that vary based on some corresponding flow on the Q record.

Structure:

fs fs(1), fs(2), . . ., fs(nprof)

nx) fs(i) - Floodway surcharges, in meters, representing the allowable surcharge to be calculated at each section with a corresponding FW record. If FS record is used, a surcharge **must be provided** for FS for each discharge specified in the Q record. Values on the FW record can override these surcharges for a specific cross-section (nprof must be ≤ 20).

COMMAND FW - FloodWays

Purpose: Mandatory record for floodway analysis to specify the encroachment method, desired surcharge, left and right encroachment limits for distance, and subareas of each cross section.

Structure:

FW mthd, target, xenclt, xencrt

- 1) mthd - Encroachment method option code. Valid values are:

0 (or blank)	equal encroachment.
1	left encroachment.
2	right encroachment.
3	set encroachment (need xenclt, xencrt).
- 2) target - the desired surcharge.
- 3) xenclt - the x-station of the encroachment constraint on left bank.
- 4) xencrt - the x-station of the encroachment constraint on right bank.

COMMAND GB - GuideBanks

Purpose: Header record for guidebanks cross-section.

Structure:

GB	secid, srd, gbtype, bsubdr, gboff, skew, ek, ck, vslope
1)	secid - unique cross-section identification code.
2)	srd - section reference distance.
3)	gbtype - code to indicate the type of guidebanks. Valid entries are: 1 Elliptical guidebanks, no skew. 2 Elliptical guidebanks, skewed. 3 Straight guidebanks, no offset. 4 Straight guidebanks, with offset.
4)	bsubd - distance that straight banks are offset from the bridge abutments (not to be confused with gboff below). This parameter is only relevant to gbtype = 4.
5)	gboff - measured normal to the flow at the mouth of the banks, the horizontal offset between the banks and the bridge abutments. Use an average value if the left and right offsets are not equal. The model places the base of the banks at this distance from the abutment stations. Side slope of the banks are equal to the bridge abutment slopes. Remaining ground points are obtained from the full-valley cross-section.
6)	skew - the acute angle that the section must be rotated to orient the section normal to the flow direction. The model applies the cosine of skew to the horizontal dimension of the section to compute cross-sectional properties. Default is zero degrees.
7)	ek, ck - coefficients used for computing the expansion and contraction losses, respectively, for the energy equation balance. These coefficients would apply only to downstream computations from the guidebank to the bridge opening. Default values are either ex = 0.5 and ck = 0.0 or the current values being propagated from downstream data.
8)	vslope - valley slope. Used to adjust elevations of x,y-coordinates for the guidebank when geometric data are propagated. Default value is zero or the current value being propagated from downstream data.

COMMAND GR - cross-section GRound geometry

Purpose: To set x, y-coordinates defining cross-section geometry.

Structure:

GR x(1), y(1), x(2), y(2), ..., x(ngp), y(ngp)

- 1) x(i) - x-coordinate, distance from an arbitrary horizontal datum on the left bank, of the ith ground point. (See figure 17.)
- 2) y(i) - y-coordinate, distance above common elevation datum, of the ith ground point. (See figure 17.)

Notes:

- 1) The parenthetical notation is for illustration purposes only.
- 2) The maximum number of x, y-coordinates that can be coded is 100, with no limit on the number of GR commands used.
- 3) x, y-coordinates are oriented from left bank to right bank facing downstream. (ngp is the total number of coordinates.)

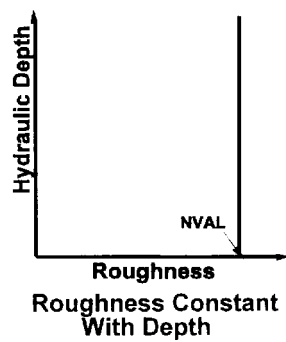
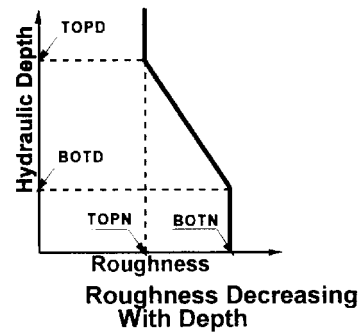
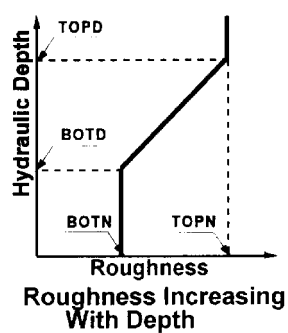
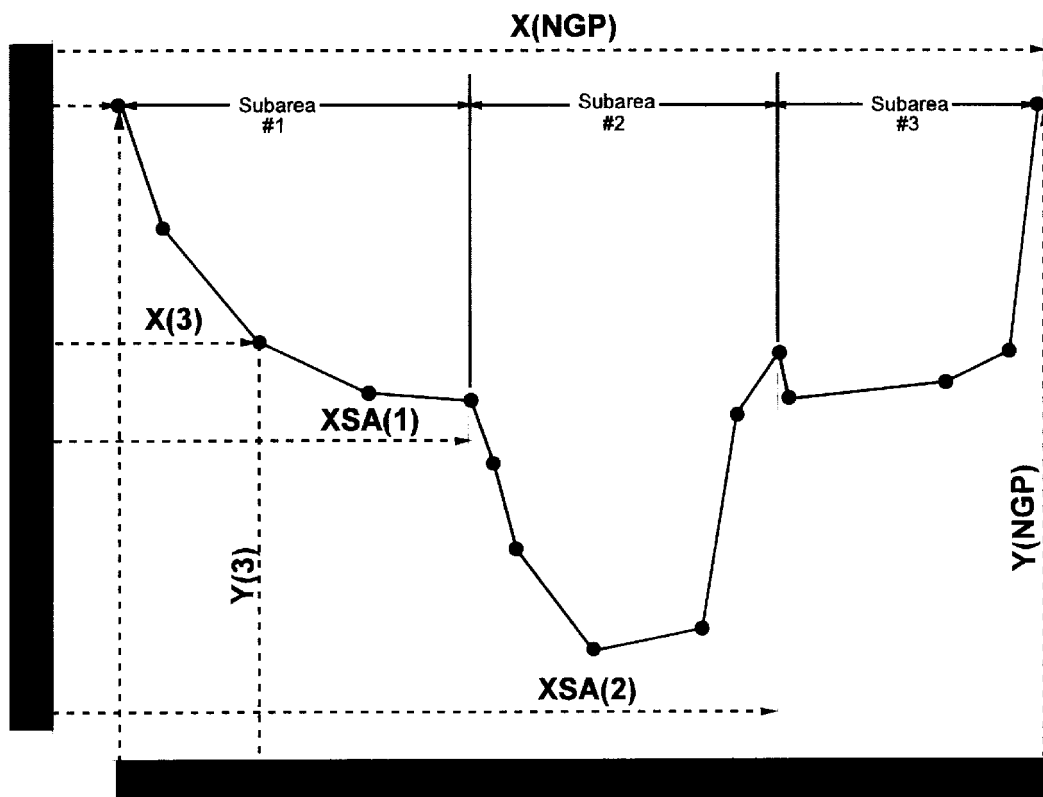


Figure 17. GR, N, ND, and SA command parameters.

COMMAND GT - cross-section Ground geometry Template

Purpose: To replace GR data for cross-sections with synthesized data from propagated template section.

Structure:

GT yshift, xliml, xlimr, scale, xorig

- 1) yshift - vertical distance that the template section elevations are to be shifted to provide appropriate elevations for the propagated cross-section.
- 2) xliml - x-coordinate of the left limit of the template cross-section to be retained to represent the propagated section.
- 3) xlimr - x-coordinate of the right limit of the template cross-section be retained to represent the propagated section.
- 4) scale - a scaling factor to be used to stretching or shrinking the horizontal dimensions of the template section geometry.
- 5) xorig - an x-coordinate in the template section which will be held to its original value when the scale factor is used.

Note: Neither xliml nor xlimr must coincide with x-coordinates specified on GR command.

COMMAND HP - Hydraulic Properties

Purpose: To compute and output hydraulic properties of cross-section.

Structure:

HP ihp, secid, elmin, yinc, elmax, q

- 1) ihp - option code indicating the following device:

ihp = 0	for table of cross-sectional properties for entire cross-section.
ihp = 1	for table of cross-sectional properties for each subarea as well as the entire cross-section.
ihp = 2	for table(s) of velocity and conveyance distribution.
- 2) secid - the section identification code for the cross-section for which properties are desired.
- 3) elmin - the minimum elevation in the cross-section for which properties are to be computed. (Default value is one-fourth of the difference between the maximum and minimum ground elevations above channel bottom.)
- 4) yinc - the elevation increment between successive elevations for which properties are to be computed. (Defaults to deltay on J1 command.)
- 5) elmax - the maximum elevation for which properties are to be computed. (Default value is the maximum elevation in the cross-section.)
- 6) q - discharge (coded for ihp = 2 only) is required to compute velocity and conveyance distribution.

COMMAND J1 - Job computational parameters

Purpose: To set computational control parameters.

Structure:

J1 deltay, ytol, qtol, fntest, ihfnoj

- 1) deltay - elevation stepping increment between successive assumptions of trail water-surface elevations when balancing the energy equation.
- 2) ytol - allowable tolerance (error) between successive computed elevations for acceptable energy equation balance. (Default value is 0.02.)
- 3) qtol - allowable tolerance (error) between discharge specified on input (Q command) and discharge computed by model in combined bridge flow and road overflow situations. (Default value is 0.02.)
- 4) fntest - Froude number test value. Computed Froude numbers greater than fncrit are cause for rejecting a computed water-surface elevation as a valid solution. (Default value is 0.8.)
- 5) ihfnoj - code to select the friction slope (or conveyance) averaging technique to be used in friction loss computations. (Default value for ihfnoj is 0.0.) Valid entries are:
 - 0 - uses geometric mean of conveyance. This field can also be left blank.
 - 1 - uses arithmetic average of conveyance.
 - 2 - uses arithmetic average of friction slopes.
 - 3 - uses harmonic mean of friction slopes.

Note: ihfnoj is applicable for all subreaches except for bridge backwater computations which always use geometric mean conveyances. To vary the averaging technique within a job requires use of FL commands.

COMMAND KQ - conveyance, K, Distribution

Purpose: To designate user-defined breakpoints of the kq segment of the approach sections.

Structure:

KQ xlkq, xrkq

- 1) xlkq - x-coordinate of the left limit of the conveyance (flow) distribution for the kq-section.
- 2) xrkq - x-coordinate of the right limit of conveyance (flow) distribution for the kq-section.

Note: The model, unless overridden by some combination of xlkq and xrkq, will place the kq-section based on the location of the computed centroid of conveyance.

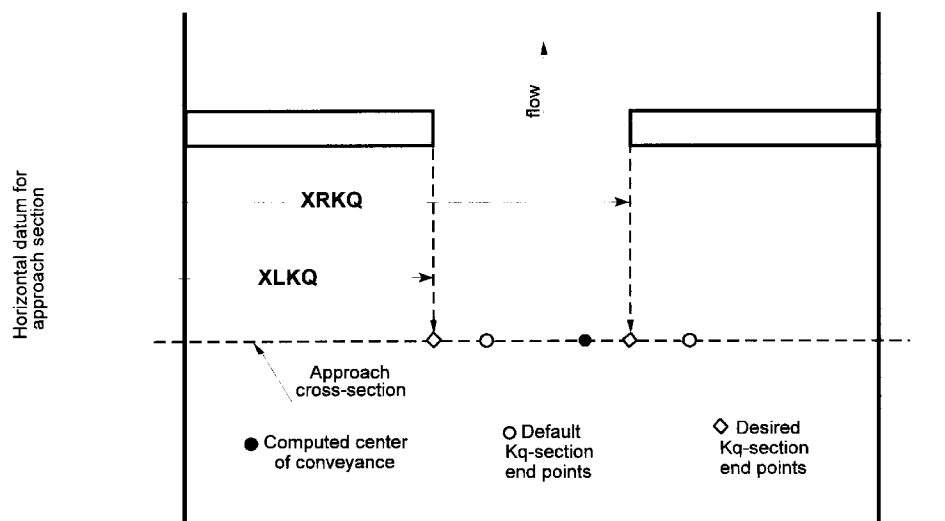


Figure 18. KQ command parameters.

COMMAND N - Manning's coefficient, N

Purpose: To specify values of Manning's "n" roughness coefficient.

Structure: (2 options)

N botn(1), botn(2), ..., botn(nsa)

-- OR --

N botn(1), topn(1), botn(2), topn(2), ..., botn(nsa), topn(nsa)

- 1) botn(i) - n-value for the ith subarea. In the absence of ND record data, this coefficient is applied over the entire range of depths. If ND command data are applicable, botn(i) is applied for the range of hydraulic depth, d of $0 < d \leq \text{botd}(i)$.
- 2) topn(i) - when ND command data are applicable, topn(i) is applied for the range of hydraulic depth, d of $d \leq \text{topd}(i)$. topd(i) values must not be coded when ND command data are not applicable.

Note: nsa is the number of subareas in the channel cross-section.

COMMAND ND - roughness coefficient, N, and hydraulic Depth

Purpose: To establish depth breakpoints for vertical roughness variation.

Structure:

ND botd(1), topd(1), botd(2), topd(2), ..., botd(nsa), topd(nsa)

- 1) botd(i) - hydraulic depth of the ith subarea at and below which the n-value of botn(i) is applicable.
- 2) topd(i) - hydraulic depth of the ith subarea at and above which the n-value of topn(i) is applicable.

Notes:

- 1) Roughness coefficients for hydraulic depths between botd and topd are determined by straight-line interpolation.
- 2) Values of botd, topd, botn, and topn must be supplied for all subareas when an ND record is coded.
- 3) nsa is the number of subareas.

COMMAND PD - Pier (or Pile) elevation-wiDth data

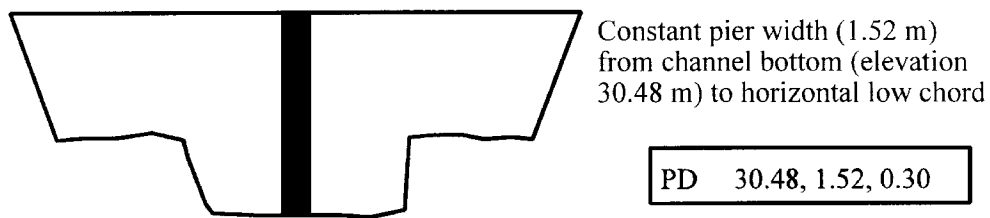
Purpose: To establish pier or pile data.

Structure:

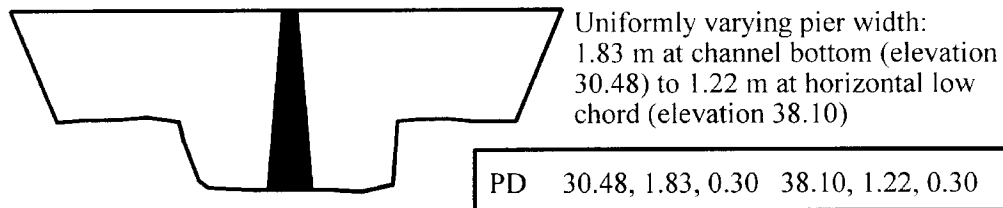
- PD ppcd, pelv(1), pddth(1), pnum(1), pelv(2), pnum(2), pddth(2), ..., pelv(npd), pddth (npd), pnum(npd)
- 1) ppcd - code to indicate whether the obstruction is in the form of piers (ppcd = 0) or piles (ppcd = 1). The adjustment to the coefficient of discharge for piers requires this distinction.
 - 2) pelv(i) - the elevation of the ith pair of elevation-width data (above datum).
 - 3) pddth(i) - the gross width of all piers (or pile bents) for the ith pair of elevation-width data.
 - 4) pnum(i) the number of piers/piles at the specific elevation pelv(i).

Notes:

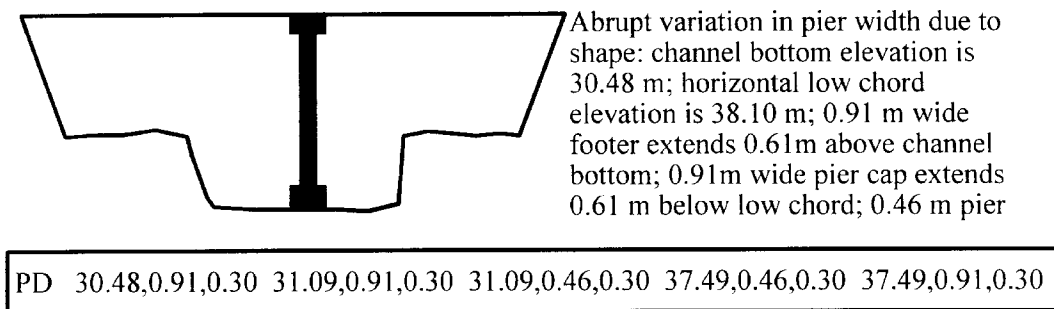
- 1) The model creates an elevation-area relationship from the elevation-width data. Straight-line interpolation is used to obtain pier (pile) area between specified elevations. A constant pier (pile) area is assumed between the highest elevation coded and the maximum bridge opening elevation.
- 2) The minimum pier (pile) data requirement is one elevation-width pair. The elevation is taken as the minimum elevation at which the pier (pile) begins. This elevation cannot be less than the minimum ground elevation in the cross-section.
- 3) If the gross pier (pile) width should happen to vary uniformly over the elevation range between minimum and maximum bridge-opening elevations, a second elevation-width pair at the maximum elevation will suffice.
- 4) For nonuniform variation of gross pier (pile) width, two elevation-width pairs are required at each elevation where there is an abrupt change in gross pier (pile) width.
- 5) An abrupt change can be: (1) additional piers coming into effect with increasing elevation; (2) changes in pier dimensions; and (3) loss of piers with increasing elevation (sloping low chord). The maximum number of elevation-width pairs is 50.



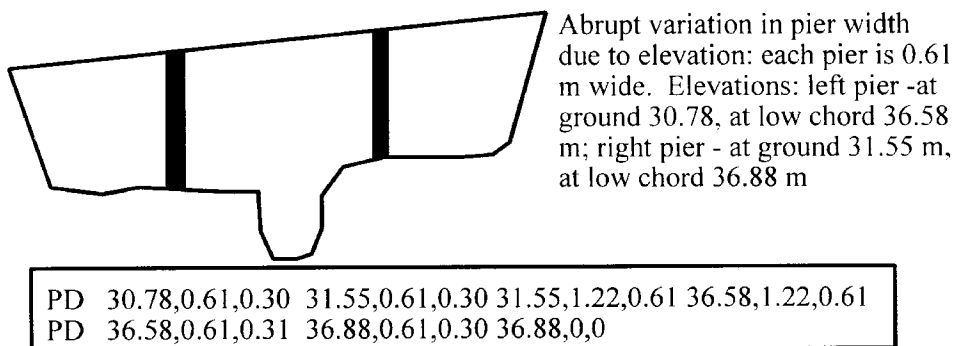
a) constant pier width



b) uniformly varying pier width



c) abruptly varying pier width with shape



d) abrupt changes in pier width with elevation

Figure 19. PD command parameters.

COMMAND Q - discharge, Q

Purpose: To specify discharge for each profile to be computed.

Structure:

Q q(1), q(2), ..., q(nprof)

q(i) - discharge for each water-surface profile to be computed. The maximum number of profiles which can be computed in a single job execution is 20.

Notes:

- 1) All entries on the Q record must be positive values (no default values are permitted).
- 2) nprof is the number of water-surface profiles (maximum equals 20).

COMMAND SA - SubArea breakpoints

Purpose: To designate horizontal breakpoints for subdivision of cross-section for roughness and/or geometry variations.

Structure:

SA xsa(1), xsa(2), xsa(nsa-1)

xsa(i) - x-coordinate of the rightmost limit of the ith subdivision. (The last xsa value to be coded is for the next-to-last subarea)

COMMAND SI - SI and english units

Purpose: Allows user the option of specifying the unit system for both input and output.

Structure:

SI (code number, 0, 1, 2, or 3)

		<u>Input</u>	<u>Output</u>
code number	0	ENGLISH	ENGLISH
	1	METRIC	METRIC
	2	ENGLISH	METRIC
	3	METRIC	ENGLISH

COMMAND SK - Slope conveyance K

Purpose: To initialize slope(s) for computing starting water-surface elevation(s) by slope conveyance.

Structure:

SK sksl(1), sksl(2), ..., sksl(nprof)

- 1) sksl(i) - energy gradient for computing the initial water-surface elevation by slope conveyance for the ith profile (m/m).

Notes:

- 1) nprof is the number of water-surface profiles.
- 2) When an SK record is used, it must contain the same number of entries (specified or default) that are contained in the Q record. The last entry on an sk record must not be allowed to default. Instead, code a negative slope.

COMMAND T1 - Title and header line 1

Purpose: To present the first line title information for identification of model.

Structure:

T1 [up to 70 alphanumeric characters to state title]

Notes:

- 1) This command is used in conjunction with the T2 and T3 commands.
- 2) The information in the free-format area of the T1, T2, and T3 command are printed on essentially every page of printed output, along with the date and time of job execution. When analyzing a series of alternative designs, it is possible to change some of the title information for each alternative without recoding all three commands. Depending on the amount of information to be changed, the user may choose to provide a new T2 and T3 command or just a new T3 command for each alternative. If a new T2 command is coded without a new T3 command, a blank line is printed for T3 command information.

COMMAND T2 - Title and header line 2

Purpose: To present the second line of title information for identification of model.

Structure:

T2 [up to 70 alphanumeric characters to state title]

Notes:

- 1) This command is used in conjunction with the T1 and T3 commands.
- 2) The information in the free-format area of the T1, T2, and T3 command are printed on essentially every page of printed output, along with the date and time of job execution. When analyzing a series of alternative designs, it is possible to change some of the title information for each alternative without recoding all three commands. Depending on the amount of information to be changed, the user may choose to provide a new T2 and T3 command or just a new T3 command for each alternative. If a new T2 command is coded without a new T3 command, a blank line is printed for T3 command information.

COMMAND T3 - Title and header line 3

Purpose: To present the third line title information for identification of model.

Structure:

T3 [up to 70 alphanumeric characters to state title]

Notes:

- 1) This command is used in conjunction with the T1 and T2 commands.
- 2) The information in the free-format area of the T1, T2, and T3 command are printed on essentially every page of printed output, along with the date and time of job execution.

COMMAND UT - User output Tables

Purpose: To specify input data control parameters (up to 3 tables can be obtained).

Structure:

UT varnos (list 1), varnos (list 2), varnos (list 3)

- 1) varnos - code numbers of stored output variables. The total number of variables in the three lists cannot exceed 50. The number of variables in each individual list is constrained only by printer line length (80 columns maximum). The model automatically uses 12 columns, thus leaving a maximum of 68 columns for the user.

Table 6. Variables available for user-defined tables (UT record).

	Variable code number	Heading
Cross-section conveyance	1	K
Cross-section area	2	AREA
Velocity head correction factor, α	3	ALPH
Momentum correction factor, β	4	BETA
Water-surface elevation	5	WSEL
Velocity head	6	VHD
Discharge	7	Q
Section reference distance	8	SRD
Maximum station in cross section	9	XMAX
Maximum elevation in cross section	10	YMAX
Minimum station in cross section	11	XMIN
Minimum elevation in cross section	12	YMIN
Boundary cross-section conveyance	13	K
Boundary cross-section area	14	AREA
Boundary velocity head correction factor, α	15	ALPH
Boundary momentum correction factor, β	16	BETA
Boundary water-surface elevation	17	WSEL
Boundary velocity head	18	VHD
Boundary discharge	19	Q
Boundary section reference distance	20	SRD
Boundary maximum station in cross section	21	XMAX
Boundary maximum elevation in cross section	22	YMAX
Boundary minimum station in cross section	23	XMIN
Boundary minimum elevation in cross section	24	YMIN
Energy grade line	25	EGL
Velocity	26	VEL
Froude number	27	FR#
Critical water-surface elevation	28	CRWS
Minimum flow depth	29	DMIN
Friction loss	30	HF
Other losses (expansion/contraction)	31	HO

Table 6. Variables available for user-defined tables (UT record) (continued).

	Variable code number	Heading
Expansion loss coefficient	32	EK
Contraction loss coefficient	33	CK
Friction slope	34	SF
Error in energy/discharge balance	35	ERR
Flow distance	36	FLEN
Straight-line (SRD) distance	37	SRDL
Stagnation point, left	38	SPLT
Stagnation point, right	39	SPRT
Skew of cross section	40	SKEW
Cross-section wetted perimeter	41	XSWP
Cross-section top width	42	XSTW
Left edge of water	43	LEW
Right edge of water	44	REW
Low steel (submergence) elevation	45	LSEL
Bridge opening length	46	BLen
Bridge opening type	47	TYPE
Flow classification code	48	FLOW
Abutment station, left toe	49	XLAB
Abutment station, right toe	50	XRAB
Coefficient of discharge	51	C
Pier or pile code	52	PPCD
Pier area ratio	53	P/A
Road overtopping elevation	54	OTEL
<i>Left Road Section</i>		
Flow over road	55	Q
Weir length	56	WLEN
Left edge of water	57	LEW
Right edge of water	58	REW
Maximum depth of flow	59	DMAX
Average depth of flow	60	DAVG
Average total head	61	HAVG
Average weir coefficient	62	CAVG
Maximum velocity	63	VMAX
Average velocity	64	VAVG
<i>Right Road Section</i>		
Flow over road	65	Q
Weir length	66	WLEN
Left edge of water	67	LEW
Right edge of water	68	REW
Maximum depth of flow	69	DMAX
Average depth of flow	70	DAVG
Average total head	71	HAVG
Average weir coefficient	72	CAVG
Maximum velocity	73	VMAX
Average velocity	74	VAVG
Flow contraction ratio (conveyance)	75	M(K)
Geometric contraction ratio (width)	76	M(G)
Conveyance of Kq-section	77	KQ
Left edge of Kq-section	78	XLKQ
Right edge of Kq-section	79	XRKQ

COMMAND WS - Water-Surface elevations

Purpose: To initialize water-surface elevations for profile computations.

Structure:

WS wsi(1), wsi(2), ..., wsi(nprof)

nx) wsi(i) - elevation representing the water-surface elevation to be used at the first cross-section of the ith profile computation (above datum).

Note: An actual elevation or null value (*) must be provided for each discharge specified on the Q command.

COMMAND XR - X-section for Road grade

Purpose: To establish road grade parameters.

Structure:

XR secid, srd, embwid, ipave, usercf, skew

- 1) secid - unique cross-section identification code.
- 2) srd - section reference distance. Should represent the location of the centerline of the road near the center of the bridge.
- 3) embwid - the top width of the embankment. This distance should reflect the breadth (measured in the direction of flow) of the broad-crested weir that the embankment becomes when overtopped.
- 4) ipave - code to indicate the road surface material. (Default is paved, ipave = 1, and graveled (or otherwise non-smooth) can be indicated by ipave = 2.)
- 5) usercf - user-specified coefficient for unsubmerged weir flow. This value will override the coefficient computed by the model.
- 6) skew - the acute angle (degrees) that the cross-section must be rotated to orient it normal to the flow direction. (Default is 0.0 degrees.)

COMMAND XS - X-Section of unconfined valley

Purpose: To reference unconfined valley cross-section (except for approach cross-section).

Structure:

XS secid, srd, skew, ek, ck, vslope

- 1) secid - unique cross-section identification code.
- 2) srd - section reference distance. Cumulative distance along the stream measured from an arbitrary zero reference point (srd may be negative). Unless overridden by FL command data, the difference between the srd values of successive cross-sections is assumed to represent the flow distance between those sections and is used to compute the friction loss component in the energy equation.
- 3) skew - the acute angle (degrees) that the cross-section must be rotated to orient it normal to the flow direction. (Default is 0.0 degrees.)
- 4) ek - coefficient used for computing expansion losses in the energy equation. (Default value is 0.5 or the last value input on a previous section.)
- 5) ck - coefficient used for computing contraction losses in the energy equation. (Default value is 0.0 or the last value input on a previous section.)
- 6) vslope - valley slope (m/m). Used for adjusting elevations of propagated geometry data. (Default value is either 0.0 or the last valley slope that was input for a previous cross-section.)

COMMAND XT - X-section of Template

Purpose: To reference template cross-section.

Structure:

XT secid, srd, vslope

- 1) secid - unique cross-section identification code.
- 2) srd - section reference distance. This provides the reference point for elevation adjustments by valley slope.
- 3) vslope - valley slope, m/m. Used for adjusting elevations of propagated geometry data. (Default value is either 0.0 or the last valley slope that was input for a previous cross-section.)

Note: This version of WSPRO now supports use of multiple cross-section templates. Second and subsequent template data overwrite previous cross-section data as they appear in the data set. Template data no longer propagates for cross-sections that precede the XT command. Users must, therefore, ensure that older data sets satisfy this convention. In other words, templates propagate to upstream SRDs for subcritical flow and to downstream SRDs for supercritical flow.

COMMAND * - comment or blank line

Purpose: To insert comments (or blank lines) in the input data sequence.

Structure:

* [up to 70 alphanumeric characters to insert comments]

Note: The free-format area can be used to code notes that may help the user keep track of the input data, or simply left blank to separate different input data (e.g., between cross-sections) to improve readability of printouts.

COMMAND *F - Free Format

Purpose: To allow data to be entered in free format.

Structure:

*F (no parameters)

Note: This command should be the first command in the data file if the data following are in free format.

REFERENCES

- 1) J. Shearman, "WSPRO Users Manual," Federal Highway Administration, Washington, D. C., Draft.
- 2) "Bridge Waterways Analysis Model: Research Report," Report Number FHWA/RD-86/108, Federal Highway Administration, Washington, DC, July 1986.
- 3) V. T. Chow, Open-channel Hydraulics, New York, NY, McGraw-Hill, Inc., 1959.
- 4) V. R. Schneider, J. W. Board, B. E. Colson, F. N. Lee, and L. A. Druffel, "Computation of Backwater and Discharge at Width Constrictions of Heavily Vegetated Flood Plains," U. S. Geological Survey Water-Resources Investigation 76-129, 1977.